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ABSTRACT

This is a final report of research in dichotic listening performance (DLP). The purposes for the research were to study the development of DLP in children and adults, to examine DLP as a function of verbal information presented in a task, to determine the contribution of perceptual and mnemonic factors affecting DLP by controlling order-of-report patterns, to examine the relationship between DLP and a child's reading status, and to explore the utility of alternative measures or expressions of DLP. Data were collected in three experiments: normal subjects with free order of report; reading-disabled and normal subjects (controls) with free order of report; and reading-disabled (dyslexic) and normal subjects with controlled order of report. In a summary of the experimental data, the report concludes that a dichotic right-ear advantage (REA) is readily obtainable in reading normal children as young as five years of age and is likely to be greater for sentences, confirming the experimental hypothesis that syntactically organized material taps the lateralized language-processing mechanism more effectively than do isolated word units. Findings also provide arguments for replacing free order with controlled order of report procedures in dichotic experiments and for using the absence of REA either for digit materials or for sentence materials as a diagnostic indicator of language impairment. (RL)

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Cerebral Dominance: Its Relation to Age and Reading

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Final Report

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Introduction

The major purposes of this research can be described as follows: (1) to study the development of DLP in children and adults; (2) to examine DLP as a function of the verbal information presented in the task, i.e., syntactically organized (sentences) vs. nonorganized (digits) material; (3) to control order of report patterns to determine the contribution of perceptual and mnemonic factors affecting DLP; (4) to examine the relationship between DLP and a child's reading status; and (5) to explore the utility of alternative measures or expressions of DLP. As many of the findings reported here will indicate, the realization of each objective cannot easily be isolated from the others. Thus, for instance, the development of DLP may only be found with syntactically organized material (see original proposal) or only in the storage phase (see, for instance, Donnenfeld, Rosen, Mackavey and Curcio, 1976). Likewise, DLP differences between children defined in terms of reading status may appear only with certain dichotic material, at a particular phase in the dichotic task, or at a later rather than earlier chronological age (Satz, Rardin, and Ross, 1971). Should these kinds of interactions emerge they should be extremely useful in elaborating the relationship between DLP and cerebral dominance, the developmental course of DLP, and its relationship to the acquisition of reading competence. The remainder of this introduction will not repeat in detail the rationale described in our original research proposal. Instead we will focus upon the several specific research objectives that have been achieved and noting where it seems appropriate discrepancies between the final report and the original proposal.

The development of DLP

To date, there have been approximately two dozen studies which examine DLP as a function of age. Not surprisingly, the dichotic material, procedures, and subject variables (i.e., age, sex, social class, race) vary considerably. One common feature they all share is their use of cross sectional age samples to infer developmental trends. Also, with only one or two exceptions (e.g., Inglis & Sykes, 1967) none has attempted to experimentally or statistically control the order in which information presented to right and left ears is reported by subjects.

Some of these studies indicate that the superiority of the right ear over the left, or right ear advantage (REA), increases with age (e.g., Bryden, 1970; Satz, Rardin, & Ross, 1971). Others have reported a decrease in REA (e.g., Geffner & Hochberg, 1971) while still others report no significant age changes (e.g., Berlin, Hughes, Lowe-Bell, & Berlin, 1974; Kimura, 1963). Undoubtedly, the discrepancies must rest in part upon the different procedures, materials and subjects employed. For instance, Berlin, et. al. (1974) observe consistent REA for 5 to 18 year olds using stop consonants, e.g., "pa," "ba," "ta." However, with several digits presented to each ear and without controlling order of report, Satz, Rardin, & Ross (1971) indicate an increase in REA over age. This second study exemplifies one of the most common problems found in developmental studies of DLP, namely the use of long strings of information without controlling order of report patterns. As we have argued elsewhere (Rosen, Curcio, & Mackavey, 1974) findings such as these are less likely to reflect perceptual or storage processes in cerebral dominance but instead probably show that children are more likely to report right ear information first as they become older. The problem in interpreting these difference is further com-

pounded by the fact that older children are able to retrieve a greater amount of information from both ears than younger children, thereby working against clear-cut REA with increasing age. By controlling order of report variables, by using different kinds of material, and by testing children ranging from 5 to 17 years, we anticipated a more complete picture of developmental changes in DLP to emerge.

The second common feature of the developmental studies is their reliance on cross sectional designs. While data derived from these methods can provide information regarding age changes, questions regarding the stability of DLP over age cannot be addressed. Even if cross sectional data were to show meaningful age trends, it would be useful to know whether children are progressing in a uniform fashion relative to one another[f]. Indeed, if stability of DLP was low or non-existent, its usefulness as a prognostic indicator of reading would become somewhat questionable.

This issue was systematically examined through the administration of identical sets of dichotic tasks to a group of children over two successive years. In addition, the availability of achievement tests in a variety of areas related to reading made it possible to determine the association between DLP and reading achievement over time. This point will be elaborated below.

The nature of dichotic material

The basic rationale for contrasting digits and syntactic material was described in our original research proposal and requires no additional elaboration here. To summarize that rationale:

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[f] Perhaps the best known instance of this phenomenon is the steady increase in intelligence over age but the failure of early infant intelligence to predict later childhood or adult intelligence (Bloom, 1964).

> Because syntax acquisition is a rather protracted affair the processing of grammatically organized information may undergo a slower, more detectable rate of cerebral lateralization over the first twelve years than the processing of isolated word units (e.g., digits). If such a developmental baseline were established, its link to reading acquisition could also be explored.

Regarding the relationship of syntactic material to reading status, evidence was cited showing that poor readers, relative to average readers,: (1) are less likely to use syntax to correct reading errors (Weber, 1970): (2) move their eyes word by word across the page and are less guided by syntactic markings (Levin & Kaplan, 1971) and; (3) show less awareness of the necessary syntactic constraints which determine the part of speech appropriate for a particular location in a sentence (Steiner, Weiner, & Cromer, 1971). Other evidence not cited in the original research proposal also supports this relationship (e.g., Rabinovitch & Strassberg, 1968; Vogel, 1976).

Perceptual and mnemonic components of DLP

If differences between good and poor readers or between younger and older children should emerge in DLP measures, the bases for the differences can occur at a variety of levels, including perceptual-attentional, mnemonic, and utilization phases. By controlling order of report patterns, dichotic techniques can specify the relative importance of the first two of these factors (See Bryden, 1967; Donnenfeld et.al., 1976). Also, as noted above controlling order of report is essential if DLP is to reflect processing capacities and not reporting preferences.

In the series of studies described in this report, the first phase of data collection report strategies were controlled in a post-hoc, statistical

fashion whereas in a second phase, order of report was controlled experimentally via subject instruction.

Reading status and DLF

Many of the points discussed thus far and in the original proposal reflect a major concern with reading status and DLP. In addition to straightforward comparisons between poor readers and age matched controls, the performances of different subgroups of poor readers on the dichotic tasks were examined. The main rationale for subgroup distinctions derives from the recognition that reading is a complex process and that disruptions of the process can occur at many phases. It would not be surprising, therefore, to find different patterns of DLP among differently defined subgroups of poor readers (see Kinsbourne, 1975, for a discussion of this issue). One of these distinctions involved chronological age group comparisons. Given the findings (Satz, Rardin & Ross, 1971) that older but not younger groups of poor readers reveal REA differences from controls, we re-examined this finding with materials similar to those of Satz et.al.(1971) (digits), with different materials (syntax), and employed the more stringent technique of controlling report patterns. A second frequently cited distinction among groups of children exhibiting reading problems is their different patterns of verbal to performance intelligence scores. For instance, Kinsbourne and Warrington (1963) present evidence to show that poor readers with substantially lower verbal than performance IQs display a pattern of deficits different than poor readers whose verbal IQs are higher than their performance IQ. Both subgroup distinctions of chronological age and intelligence patterns were examined in the analyses presented below.

A final set of analyses relating DLP to reading status were conducted on the longitudinal portion of the data. Since DLP measures and Stanford

Achievement test (SAT) scores (Kelley et al., 1964) on reading and word usage abilities were collected in 1975 (T_1) and 1976 (T_2), it was possible to relate these two sets of measures in a variety of ways: (1) DLP at T_1 was related to SAT at T_2 to determine whether dichotic performance would enable future predictions of level of reading ability; (2) DLP at T_1 was related to changes in SAT from T_1 to T_2 to determine whether certain aspects of dichotic performance (e.g., right ear scores, syntactic material) was predictive of changes in reading ability over time and; (3) changes in DLP from T_1 to T_2 were related to similar changes in SAT to determine whether the two sets of measures revealed similar patterns of growth over time. While this third set of correlations contains certain procedural problems (Wohlwill, 1973), it offers a rather detailed examination of developmental relationships between reading and DLP.

Alternative expressions of DLP

The most typical method of expressing DLP is in terms of number or percent correct of information correctly identified in the left and right ears. From this information various expressions of REA can be derived. While correct identification was the principal measure of DLP, the usefulness of two other measures was explored. The first reflected the manner in which subjects organized their reporting of the dichotic material. Several investigators have explored frequency of different report patterns (e.g., organization by ear, by material, etc.) for distinguishing children varying in intelligence level (Witelson & Rabinovitch, 1971) and reading ability (Leong, 1975). Although pattern of report was not a primary focus of this study, it does affect our principal measure of DLP and, if for no other reason, it deserved examination. Patterns of report were divided into seven categories: R-0, indicating that the subjects reported some or all of the information presented to the right ear and nothing from the left ear; R-L which meant that some right ear information followed by left ear information

was given; R-L-R, indicating an alternating pattern initiated by information from the right ear; three additional categories when left ear information was given first, L-O, L-R, L-R-L; and, finally, a miscellaneous category consisting of instances where the pattern was not clear or information not presented on the dichotic tape was reported.

The second measure examined was the tendency of subjects to follow instructions. In pilot work we noted that when subjects were instructed to report all right ear information first and then left ear information (or vice versa), the compliance with instructions varied as a function of several factors. For instance, children seemed to be more able to comply with instructions when right ear information was to be reported first than when it was to be reported second. The ability to follow instructions has received practically no attention in the literature, although it may distinguish children of different ages and different reading levels. For instance, a strong lateral awareness (associated with both age and reading) could assist in perceiving and maintaining a distinction between the different sources of dichotic input. Also, the ability to follow instructions by reporting right ear information first on some trials and left ear information first on other trials could be interpreted as a capacity to adopt more organized, flexible strategies in the processing of auditory information. Macoby (1969) has suggested that such capacities are age related, although its relationship to reading status has not been determined.

Method

The set of dichotic investigations to be reported fall into two distinct types, both chronologically and methodologically. In the beginning phases of this research (Spring, 1974) order of report patterns were not experimentally controlled, i.e., subjects were not instructed to report dichotic input in any particular order. From initial analyses of these data it became clear that not controlling report patterns in any fashion was not sufficiently informative and to control report patterns in a post hoc statistical manner resulted in the elimination of substantial amount of data (see Studies I and II). Therefore, in the Spring of 1975 the longitudinal phase of the research using free order of report (FOR) procedure was completed and a new sample using controlled order of report (COR) was initiated (Study III).

Methodological procedures specific to each of these three studies (e.g., subject characteristics, collateral measures, design, etc.) are given separately within each of the appropriate sections. The following section describes the general method common to all of the studies.

Dichotic material

The dichotic material consisted of two kinds of information, strings of single digits and words arranged into sentences. The sentence material consisted of twenty-six pairs of sentences ranging in length from three to six words per sentence. Declarative, interrogative, nominalization, passive and reflexive sentence constructions were used. A complete list of these sentence pairs and their order of presentation are given in Appendix A. The digit material was comprised of single digits. Altogether forty trials of digit material were presented, ten trials each of 1, 2, 3, and 4 digit pairs.

Within any given trial, the digits were randomly paired with the restriction that no digit could be repeated. The digit pairs and their order of presentation are also given in Appendix A. Presentation rate for the digits was two pairs per second.

Stimulus preparation and control

All digit and sentence material was recorded and assembled devoid of prosodic intonation. Each element (i.e., digit, word) was recorded separately on tape (with a male voice) and trials for strings of digits or sentences were prepared by assembling these individual elements.

The onset of each pair of digits/sentences over the two channels was made simultaneous via a PDP-12 program enabling the conversion of the analog signal representing the word to digital form. The beginning of the "digital word" was defined and stored on LINC tape for assembly onto the two channels For the sentence material offset - or end of sentences - also were made to coincide by defining the ends of the last words in the sentences and, where necessary, contracting or expanding the overall length of a sentence so that sentence pairs began and ended at the same time. Overall stimulus intensity (averaged over a sentence or digit pair) were equated across channels.

All dichotic material was presented via KLH headphones (Model 80) on a Tandberg stereo recorder (Model 9041X). Output levels through the headphones were equated to 72 decibels using a full track 1000 Hz tone. Further, the placement of the stereo headphones on each subject was counterbalanced, i.e., half the subjects received channel 1 in the left ear, channel 2 in the right ear, while the remaining subjects had the channels reversed.

Procedures

All dichotic testing was conducted in a quiet room. Following a warm-up, familiarization period in which practice dichotic information was given, the test material was presented and subjects were instructed to report as much

information as they could from both channels after each trial. The order in which the syntactic and digit material was given over subjects was counter balanced within each of the studies reported below.

Experiment I

Dichotic Listening - Normal Subjects with Free Order of Report

The first experiment conducted involved the dichotic presentation of sentences as well as digit pairs to three age groups, viz., fifteen kindergarten children ($\bar{X}_{CA}$=5.5 years), twenty third grade children ($\bar{X}_{CA}$=8.6 years) and twenty college adults ($\bar{X}_{CA}$=18.6 years). All subjects were right handed. The school children were selected by their teachers. Teachers were requested to select "average" children, paying particular heed not to include any child with either an overt or suspected learning problem. Data from these subjects provide 1) an indication of the level of performance to be expected among normal readers using our material and procedures, 2) information on the relative effectiveness of the two classes of material in revealing ear differences, 3) information regarding age changes in group or material induced effects as reflected in cross sectional data.

A three-way ANOVA involving one between factor (Age) and two within factors (Material and Ear) was performed. Table 1 displays the means for each of these factors. As expected, older subjects performed better than younger subjects ($F=142.3$; $df=2, 52$; $p<.001$). Sentence material was reported more accurately than digit material ($F=418$; $df=1, 52$; $p<.05$). Right ear performance was better than left ear performance ($F=28.6$; $df=1, 52$; $p<.001$). All interactions involving these factors were also significant. Figure 1 illustrates the Group X Material interaction ($F=7.8$; $df=2, 52$; $p<.01$). Post-hoc tests confirm the trends evident in the figure. The performance of the youngest children is not benefited by listening to syntactically organized material ($t=1.29$; $df=14$; $p=.22$). A ceiling effect seems to be evidenced by the adult group ($t=1.91$; $df=19$; $p=.07$) with the result that the third grade group displays the greatest change in performance as a function of the type

of material with a clear advantage emerging under the syntactic condition ($t=4.61$; $df=19$; $p<.001$).

The significant Group X Ear interaction ($F=4.2$; $df=2, 52$; $p<.05$) reflects a trend toward decreasing ear asymmetry from the kindergarten to the adult group. See Figure 2. Again, a ceiling effect is evidenced by the adult group in that both left and right ear scores are at nearly errorless levels. Figure 3 reveals the basis of the significant Ear X Material interaction ($F=60.8$; $df=1.\ 52$; $p\ .001$). Whereas right ear performance is greater for sentences than for digits, thus consistent with the main effect for material, the outcome is reversed for the left ear where digit performance exceeds that for sentences ($t=2.90$; $df=54$; $p=.005$).

The significant Group X Material X Ear interaction is shown in Figure 4 ($F=22.5$; $df=2, 52$; $p<.001$) and serves to demonstrate that the trend toward decreasing ear asymmetry from the kindergarten to the adult group revealed in the Group X Ear interaction, Figure 2, occurs only for sentence materials. Ear asymmetry is generally smaller and certainly more consistent across age groups when using digit materials.

The finding of an increased ear asymmetry for sentence material, represented by the significant Ear X Material interaction (Figure 3) is consistent with the view that sentence materials tap the language processing mechanism more effectively than do digit lists. The significant Group X Material X Ear interaction (Figure 4) shows that this advantage is largely attributable to the two younger groups. In the case of the adult subjects it is difficult to do more than acknowledge the likely presence of a ceiling effect in ear performance that obscures whatever differences might exist across stimulus categories.

It maybe that the greater ear asymmetry for sentences of the two

younger groups (Figure 4) and the superiority of left ear digit performance relative to sentence performance are related. It is known that subjects tend to organize and cluster their responses according to ear when relatively brief interpair intervals are employed. That is, first one ear message will be reported then the other. It is also known that the right ear tends to be the ear of first report (Bryden, 1967). If each of these common tendencies were to exist in the present experiment, then certainly the form of the Ear X Material interaction would be clarified. It merely needs to be recognized that once a report is initiated, a sentence will cohere and be less vulnerable to opposite ear intrusion than a random digit sequence.

Given these contingencies, when using sentence materials, not only would left ear performance suffer through delayed reporting, but right ear performance would be the necessary beneficiary of such sequencing. In other words, ear performance and order of report are potentially confounded in an experiment employing free order of report. Subject protocols were examined in order to evaluate this possibility.

The tendency to begin the report of the dichotic message with material delivered to the right ear was confirmed for both sentences and digits, viz., 62% versus 38%. These figures are comparable to those reported by others (Bryden, 1967). The likelihood of maintaining ear separation, however, was much greater for sentences. For sentence material, when the right ear was the lead ear, it was interrupted by material delivered to the left ear less than 10% of the time. On the other hand when digit materials were employed, the right ear report was interrupted slightly more than 50% of the time.

Concerning the contribution of pattern of report to the form of the

Ear X Material X Group interaction it was found that children in the kindergarten and third grade groups were far more likely than adult subjects to provide a report from only the right ear. Moreover this tendency was especially pronounced for the sentence materials (Table 2). We have then a situation in which 1) right ear leads are more common than left ear leads and 2) when that occurs with sentence material there is little likelihood of interruption by left ear content and 3) when the younger subjects complete their report of the right ear message, the left ear message is no longer available for report. These outcomes are entirely consistent with the form of the Ear X Material X Group interaction seen in Figure 4 in which ear asymmetry for sentences declines with age. In aggregate, these findings argue for a reanalysis of the data with order of report as a statistical post hoc control.

The form of this ANOVA resembles the first except for the inclusion of order of report (right-left versus left-right patterns) as an additional within factor. The means for each of these factors is given in Table 3. Those subjects that had no instances of ear separation maintained across both classes of material, thereby enabling a clear comparison of first versus second ear report could not, of course, be included. An adequate N for reanalysis remained, however, viz., kindergarten = 11, third grade = 15, adults =13.

Each of the main effects for which significance was obtained in the original analysis remained significant in the reanalysis. Group ($F=27.9$; $df=2, 36$; $p<.01$), Material ($F=82.4$; $df=36$; $p<.01$), Ear ($F=21.0$; $df=36$; $p<.01$). Whereas the main effect for Pattern was not significant, the Pattern X Ear interaction was significant and that is shown in Figure 5. It is clear from the figure that the decrement from first to second order of report is greater

for the right-left sequence than for the left-right sequence. Given the existence of a greater decrement for the right-left sequence and the greater likelihood of that sequence when listening to sentences as opposed to digit lists, the form of the Ear X Material interaction of Figure 3 becomes comprehensible. The elevation in left ear performance for digits relative to sentences is no longer an anomaly. It is the Ear X Material interaction of the reanalysis, in which order of report is statistically controlled, that is needed to determine whether the greater right ear advantage (REA) for sentence material of the original analysis is due entirely to this conjoining of material and report pattern.

Figure 6 illustrates the new Ear X Material interaction and it can be seen that the interaction retains a marginal significance ($F=3.5$; $df=1, 36$; $p<.05<.10$). It becomes useful to consider the remaining significant interaction at this point as it involves both the Ear and Material factors. The four-way interaction involving Group, Pattern, Material and Ear is shown in Figure 7.

While the interpretation of a four-way interaction is not an enviable task, one feature of Figure 7 is of particular interest. The disparity in performance level between ears is especially great for the two younger groups when the report of sentence material is delayed. Looked at another way, the considerable drop (30 points) in performance level that is observed when report proceeds from right to left is actually slightly reversed (4 points) when the right ear is the delay channel. Thus for sentence material, right ear second yields scores that are at least the equal of left ear first scores. The adult group again encounters a ceiling effect that precludes the demonstration of any increment. The left ear as the ear of first report achieves a nearly perfect level of performance, 96%.

The borderline significance of the Ear X Material interaction (Figure 6) and the significant four-way interaction involving Ear X Material X Group X Pattern (Figure 7) encourage the tentative conclusion that syntactically structured materials are capable of yielding a REA that is substantially greater than that achieved by use of the more traditional digit lists. This conclusion needs to be subjected to further test in a study involving the control of order of report by means of instructions rather than by post hoc statistical control.

Experiment II

Dichotic Listening - Reading Disabled and Normal Controls with Free Order of Report

The dichotic testing program on reading disabled children was begun and well underway prior to the completion of the data analysis described in Experiment I. The reading disabled subjects and their controls therefore were also run under free order of report conditions and all analyses incorporate post hoc statistical control of order of report.

All subjects were obtained from elementary schools in the Newton, Massachusetts school system. Subjects in the reading disabled group were initially identified as having unusual reading difficulties by their classroom teachers, subsequently administered the Newton Elementary Test for Learning Disability, and on the basis of that test receiving instruction in reading by specially trained learning disability tutors. All children were described by their teachers as right handed. This was confirmed by asking the children to write their names. Instances of disagreement between a teacher's assessment of handedness and the writing task were rare. Those few instances were discarded. We then examined school records, which were unusually complete, and interviewed tutors to obtain information on I. Q.

level, medical history, emotional stability, language(s) spoken at home etc. If any circumstances were uncovered here (e.g., low WISC, parent institutionalized) that could contribute to a disruption of reading performance that child was omitted from testing and/or data analysis.

All children, normal and controls, were in the second, third, and fourth grades at the time of initial testing and were in the age range 8.5 to 10.2 years. Sentence materials were administered to all children and digit materials to some of these children. All available children were retested nine to twelve months later.

The first analysis to be reported involves the performance of thirty-six learning disabled (L. D.) children and nineteen controls on sentence materials. A three-way ANOVA involving one between factor (Group) and two within factors (Ear and Order) was performed. Table 4 displays the means for each of these factors. The control group performed at a higher level than the L. D. group ($F=8.5$; $df=1, 53$; $p<.01$), right ear performance was superior to left ear performance ($F=26.0$; $df=1, 53$; $p<.05$), and the ear of first report was superior to the ear of delayed report ($F=26.0$; $df=1, 53$; $p<.01$). One interaction, Ear X Order ($F=5.1$; $df=1, 53$; $p<.05$), was significant and is depicted in Figure 8. It can be seen that the left ear is particularly debilitated by delay of report.

When these subjects were retested the following year* a similar pattern of results was obtained. See Table 5. Although the drop from first to second report was again greater for the left ear (9.3 points) than for

* The retest involves thirty-six L. D.'s and twelve normals. Attrition is from two sources. Either the children were not available for retesting or they did not have responses that were amenable to the post hoc control for order of report. Four control subjects were lost for the former reason. Two L. D. subjects were lost for the latter reason and were replaced by two others matched for age.

the right ear (7.1 points), the Ear X Order interaction was not significant ($F<1.0$).

A comparison of Tables 4 and 5 reveals a slight increment in performance levels from one testing to the next. However, a separate ANOVA for each group based only upon those subjects that were in each analysis (twelve controls, thirty-four L. D.'s) revealed the increment to be non-significant. The cross-sectional data reported in the first section of this report suggest that although a hard performance ceiling has not been encountered, the increment to be expected in a single year for subjects in this age group is not substantial. It is perhaps most noteworthy that sentence materials are capable of discriminating between L. D. and reading normal groups, high levels of performance not withstanding.

Eight control and thirty L. D. subjects in the retest group had scorable protocols for both sentence and digit materials. This enabled a four-way ANOVA involving one between (Group) and three within factors (Ear, Order, Material). As before the main factors of Group ($F=7.3$; $df=1, 36$; $p=.01$), Ear ($F=7.7$; $df=1, 36$; $p<.01$) and Order ($F=23.4$; $df=1, 36$; $p<.01$) were significant. In addition, sentence material (84.4% versus 70.0%) was reported with greater accuracy than digit lists ($F=21.1$; $df=1, 36$; $p<.01$). There were no significant interactions.

One strong conclusion that bears on the design of dichotic listening studies is inescapable from the experiments reported herein. In all but rare and unusual circumstances, order of report must be experimentally controlled, preferably by instruction rather than by post hoc statistical treatment. In the absence of such control, the tendency to initiate report with the right ear can easily enhance or generate an artifactual REA. While this is true even when a single category of stimulus material is used, the issue

of pattern of report becomes more critical if comparisons are attempted across categories of material such as sentences and digits. Our first experiment demonstrated that ear separation in report is more likely with sentence than with digit material. Conversely, alternation in report across ears is relatively more common with digit materials. A similar finding was obtained in the studies involving the Newton L. D. and control children.

Pattern of Report for Children in Experiment II

As indicated in the introduction, we have come to distinguish among seven categories of response patterning, viz., single ear, either right or left only, is reported (RO or LO); one ear reports first followed by the other (LR or RL); an alternating pattern of response is observed (such as RLR or LRL); and miscellaneous (e.g., no report, unintelligible, not on tape, etc.). Table 6 displays the order of report patterns for a combined group of sixteen normal and thirty-seven L. D. children for each of two categories of material.

Several features of Table 6 are worth noting. Right ear leads occur half again as frequently as left ear leads, single ear reports and pure ear separation patterns are more common for sentences than for digits, and alternating patterns of response are considerably more common for digits than for sentences. Each of these effects is of convincing magnitude without a test of significance.

To recapitulate, the situation that one is confronted with in a free order of report experiment is a clear bias toward REA (e.g., right ear leads occur 60% of the time). In an effort to control for that bias, data analysis can be limited to pure ear order separations such as LR and RL. Although this is probably the best that can be done, the data presented in Table 6, in conjunction with the attrition rate of about 30% reported in Experiment I

(fifty-five subjects in the initial analysis, thirty-nine in the reanalysis), makes it clear just how wasteful this is of both experimental effort and data. A substantial proportion of subjects will provide no salvagable data (no responses in the RL or LR category) and the remaining subjects will contribute only a fraction, too often a small fraction, of their responses into the data pool. For these reasons, we concluded that a meaningful analysis of dichotic listening performance in L. D. children would require a fresh experimental attack involving controlled order of report.

Experiment III

Dichotic Listening - Reading Disabled and Normal Controls with Controlled Order of Report

The L. D. sample for the next phase of our study was obtained from the Carroll School in Lincoln, Massachusetts. The Carroll School provided a particularly appropriate subject pool in that it is a school specifically and exclusively for dyslexic children from second grade through high school age. Prior to admission to the school extensive clinical testing is done and those accepted are all of at least average intelligence, are not emotionally disturbed and have been diagnosed as having no disability other than dyslexia.

Full scale WISC (Weschsler, 1974) scores were available for all L. D. children. In addition, for some of the children the following individual scales from the Stanford Achievement Test (Kelley et al, 1964) were administered by the school psychologist: Reading Achievement, Paragraph Meaning, Spelling, Vocabulary, and Word Meaning. Performance on these scales was assessed twice over a one year period (T_1 and T_2) and was expressed as a scaled score, i.e., in terms of the child's ranking relative to other children of the same age.

Sentence and digit materials were administered to seventy-three right-handed dyslexic children using a controlled order of report procedure. The age of the children ranged from 7.8 to 16.0 years with a mean age of 11.7 years. Control subjects, as before, were obtained from the Newton, Massachusetts school system and ranged in age from 7.1 to 15.9 years with a mean age of 11.6 years. All ninety-four control children were right handed. As in Experiments I and II handedness was determined by teacher description and confirmed by our own observation of the child writing his/her own name.

The children of both groups were instructed in order of report by means of a "point and touch" procedure. The labels left and right and any confusions relating to them were thereby avoided. Ten unscored practice trials were employed, each involving a single digit pair. Instructions were easily obeyed in the practice trials. The statistical analyses to be reported include only those trials in which instructions were followed.

A four-way ANOVA involving one between factor (Group) and three within factors (Material, Ear, and Order) was performed. Table 7 displays the means for each of these factors. All main effects are highly significant. The control group performed at a higher level than the L. D. group ($F=46.5$ $df=1, 166$; $p<.01$), right ear performance was superior to left ear performance ($F=79.3$; $df=1, 166$; $p<.01$), performance on sentence material was superior to performance on digit material ($F=126.4$; $df=1, 166$; $p<.01$) and the ear of first report was superior to the ear of second report ($F=270.2$; $df=1, 166$; $p<.01$).

A number of two-way interactions also achieved significance. Figure 9 depicts the Group X Material interaction ($F=12.4$; $df=1, 166$; $p<.01$). It is clear that the Material difference is greater for the L. D. than for the control group. This appears to be principally attributable to the low digit

performance of the L. D. group. The L. D. group also appears to suffer more through delay of report than does the control group. This is evidenced by the significant Group X Order effect ($F=8.5$; $df=1, 166$; $p<.01$). See Figure 10. We again find evidence that sentence materials are capable of generating a greater ear asymmetry than digits in the significant Ear X Material interaction shown in Figure 11 ($F=10.1$; $df=1, 166$; $p<.01$). It is interesting that this material difference emerges even in the face of an apparent ceiling effect encountered by the right ear in reporting sentence material. The significant Material X Order interaction ($F=9.0$; $df=1, 166$; $p<.01$) reveals that digits are more impaired by delay of report than are sentences. See Figure 12.

One higher order interaction achieved significance, viz., Group X Material X Ear ($F=20.4$; $df=1, 166$; $p<.01$). See Figure 13. Post hoc "t" tests revealed that whereas the Ear difference was significant for both the L. D. and normal children on sentences ($t=7.79$; $df=72$; $p<.001$ for L. D.'s and $t=7.23$; $df=93$; $p<.001$ for controls) the Ear difference for digits achieved significance only for controls ($t=4.48$; $df=93$; $p<.001$). Ear asymmetry does not emerge for the L. D. group when listening to digits ($t=1.25$; $df=72$; $p>.05$). It can thus be concluded that sentences are highly reliable materials for revealing an ear difference in a dichotic listening situation. In contrast, materials as linguistically primitive as simple digit lists may be quite ineffective in revealing this difference when applied to a group, such as the rather pure L. D. sample of the present experiment, where cerebral specialization for language may be less crisp than in language normal children.

Pattern of Report

How well are subjects able to follow instructions to first report the

message delivered to a specified ear before reporting the message to the opposite ear? Table 8 shows the distribution of responses across the seven response categories for both right ear lead and left ear lead instructions. It is apparently easier for subjects to adhere to the right ear lead (REL) instructions than the left ear lead (LEL) instructions. Thus for sentence materials under REL instructions 84.5% of the responses are in the RO and RL categories* whereas under LEL instructions the percentage of responses in the LO and LR categories drops to 70.2%. The fact that these figures reduce to 50.6% and 43.5%, respectively, when listening to digit lists, indicates that the change in material substantially increases the difficulty of adhering to instructions. Table 8 documents the sharp increase in the incidence of channel switching (i.e., RLR and LRL responses) when listening to digit lists.

This suggests an interesting tie-in to our finding that the Carroll children were particularly impaired on delayed report - the Group X Order interaction shown in Figure 10. If the ability to retain the content of the delayed channel is impaired in the L. D. group, then it is to be expected that this group could also have greater difficulty than controls in adhering to the instructions. The instructions not only require that the dichotic message be reproduced, but impose the additional processing and mnemonic burdens of tagging the side of input, retaining the tag, and making use of it in the report of the message.

A series of "t" tests were performed comparing the ability of the two groups to adhere to instructions across the two classes of material. The outcome is shown in Table 9. As expected, in three of four comparisons

* According to a strict criterion, ear switching as in the RLR category violates the instructions and is not included.

(two conditions of ear lead X two classes of material), the controls are clearly superior to the L. D. children in their ability to follow instructions. The one instance of borderline significance is in the predicted direction. It appears that when listening to digit materials, a majority of subjects in both groups have difficulty in maintaining clear ear separation under LEL instructions.

Does the controlled order of report procedure extract any penalty in terms of the amount of material that a subject is able to report? Generally not. Table 10 compares the performance of the thirty L. D. and eight control children tested on both sentence and digit material in the free order of report procedure of Experiment II with the children tested under the controlled order of report procedure of Experiment III. While differences in the composition of the subject groups force conclusions to be approximate, it appears that performance differences between the two procedures is not great. Generally any advantage that occurs, attaches to the controlled order of report procedure. The digit performance of the L. D. group departs from this trend. We have already noted the existence of a significant Group X Material interaction in connection with Experiment III (See Figure 9).

In summary then, the controlled order of report procedure has much to recommend it. First, and most conspicuous, there is the absence of subject attrition under this procedure. Whereas about 30% of the subjects reported on in Experiment I had to be dropped from the reanalysis due to the absence of appropriate trials for control of order of report, no subjects were lost for this reason in Experiment III. Second, the controlled order of report procedure provides an additional useful dimension on which to compare L. D. and control subjects, viz., the ability to follow instructions. We have shown that L. D. children are impaired on this measure (Table 9). Third,

even with the additional requirement of ordered report, performance generally remains at a level comparable to that achieved under free order of report (Table 10).

Table 9 revealed that control subjects are, by and large, more likely to adhere to instructions than are the L. D. children. How otherwise do the two groups differ? Do L. D. children distribute their responses differently than the control children across the seven response categories? Table 11 displays the percent of trials in each category for children in the two groups and for each class of stimulus material.

The distribution of responses suggest that when listening to sentences, L. D. children are more likely to 1) engage in channel switching (RLR and LRL), 2) lose all left ear input and 3) give unscorable responses (other). Except for the incidence of channel switching, a similar pattern is evident with digits. The successful avoidance of channel switching is difficult for children of both groups when listening to digits. In as much as the tests of significance are not independent in this design, the p values shown in Table 11 are only suggestive.

One Year Later

Forty-two of the L. D. children originally tested at the Carroll School were available for testing one year later. In this ANOVA, performance at $Time_1$ versus $Time_2$ was regarded as the Group factor. In other respects the ANOVA was patterned after the Carroll L. D. versus Newton Control analysis with Ear, Order, and Material as additional factors. The average performance of these forty-two subjects at $Time_1$ was 74.0% and this compares almost exactly with the 73.4% of the larger group of L. D.'s (N=74) at T_1. It is therefore unlikely that the reasons leading to the continued availability of these subjects introduced any sample bias. This is supported by the results

of the ANOVA, which apart from the absence of any Group main effect or interaction was very similar to that already reported between the Newton Controls and the Carroll L. D. children. The absence of a group effect here simply means that the increment in performance of the L. D. group from T_1 to T_2 (74.0% to 76.6%) was not significant (F=1.1). Dichotic performance of the L. D. group at T_2, in other words, has not yet achieved parity with that of a group of normal readers of younger average age. It would be necessary to test even older dyslexic children or even adults with a continuing reading problem to determine whether dichotic performance will ever achieve the level attained by normal readers.

I. Q. and Dichotic Listening

Kinsbourne and Warrington (1963) have claimed that different categories of reading disability are associated with rather different I. Q. profiles. For example, reading retarded children that make spelling errors involving incorrect sound substitutions and also are slow to acquire speech are apt to have verbal I. Q.'s well below their performance I. Q. On the other hand, those reading retarded children that show no delay in speech acquisition and evidence spelling errors involving letter order are apt to have performance I. Q.'s that lag behind their verbal I. Q. It was therefore of interest to determine whether such discrepant I. Q. profiles are associated with different levels of performance on our dichotic measures. From the group of seventy-three T_1 L. D. children we identified a group of forty-two having contrasting I. Q. profiles. Twenty-eight of these had a verbal I. Q. in excess of the performance I. Q. and fourteen had a performance I. Q. fifteen or more points in excess of the verbal I. Q. The particular divisions established necessarily reflect the distribution of I. Q. patterns available in the sample. Since the Carroll children undergo an unusal amount of test-

ing and screening prior to acceptance, extreme discrepancies in I. Q. were relatively uncommon. The means of the two L. D. groups and thirty age matched normal controls is shown in Table 12.

A simple one-way ANOVA across the three groups confirmed the existence of a group effect ($F=7.0$; $df=2, 69$; $p<.01$). Confidence intervals established for the individual means again confirmed that the controls performed significantly better than either group of L. D. subjects. The two I. Q. groups achieve a marginal separation from each other with a slight advantage accruing to the V+P L. D. group.

It will be recalled from Figure 13 that whereas both control and dyslexic children show a REA when listening to sentence materials, the REA is lost for the dyslexic group when listening to digits. A series of "t" test comparisons for each of the three groups under discussion shows that this conclusion remains in effect for L. D. children of either I. Q. profile. See Table 13.

Cross-Sectional Age Trends

Can any age trends be discerned when the dichotic performance of younger subjects is compared to that of older subjects? In addition to the correlational analyses to be discussed in the next section of this report, the data from T_1 L. D. and control subjects was reanalyzed with Age introduced as a factor in addition to those of Ear (left-right), Material (sentences-digits), Order (first-second), and Group (L. D.-control). An age split at approximately the mean of the two groups was established, viz., 12.0 years. This division yielded N's of 30 and 42 younger and older L. D. children, respectively, and N's of 49 and 45 in the case of the control subjects.

The results of this analysis are necessarily highly similar to those already reported for the Carroll T_1 and control subjects since of course both

the subjects and their scores are shared in the two analyses. The specific item of interest is the statistical behavior of the Age factor including its interaction in the Ear, Material, Order, and Group factors. The outcome of this "new" ANOVA was nearly identical to that already reported. While the performance of the older subjects was indeed higher than that of the younger subjects (80.5% versus 77.6%), the difference was not significant ($F=2.94$; $df=1, 162$). Further, Age entered into only one significant interaction, viz., Age X Ear ($F=4.84$; $df=1, 162$; $p<.05$). This is shown in Figure 14. It can be seen that the increment in performance as a function of age is greater for the left ear than for the right ear. The statistical significance of all other main factors and their interactions remains unchanged.

Post hoc "t" tests confirmed our earlier finding that while ear differences on sentence materials are significant for both L. D. and control subjects, they are significant only for controls on digit materials. See Table 14.

A Description of the Correlational Analyses

A set of correlation matricies were developed in order to ascertain (1) the strength of the interrelationships that might exist among our several dependent measures, and (2) the possible utility of these variables as predictors of future behavior. The latter was assessed by inter-correlating the measures obtained on the same subjects over two consecutive years.

In essence two large correlation matricies were constructed. The first of these was concerned with the performance characteristics of the L D children; performance which was evaluated independently on two successive years. The second matrix examined similar behavior in aged matched normal readers, although these observations were made within a single year, thus precluding the possibility of looking for longitudinal trends in our normal control group (cross sectional age changes in the latter group have been explored through analyses of variance and these are reported elsewhere in this report).

The larger analyses involving an examination of L D performance will be examined first. This correlation matrix was comprised of fifty-three different variables which in turn generated (53 x 52) 2756 cells, where the number of observations per cell varied from a high of forty-two to a low of eleven, each subject not having been assessed on each variable (See Table 15).

Given the size of this correlation matrix it is not at all suprising that a considerable number of intercorrelations were found to achieve a $p < .05$ level of significance. With a cell size of 2756 we would expect that approximately 140 outcomes would achieve significance by chance alone. From

this it is evident that each of our 53 variables will, on the average and by chance alone, generate a significant correlation with 2 or 3 other variables. This consideration presents us with the problem of discriminating between random findings and substantive outcomes. For example, consider the Age variable which was found to significantly and positively correlate with four other variables in 1975 (Response Only to Left Ear Syntactic Input [LOS], Paragraph Meaning [PM], Spelling [SP], Vocabulary [V]) and three variables in 1976 (Total Left Ear/Digit Performance [GSLD], Initial Response to Left Ear Syntactic Input [LIS], SP). While this represents a greater number of significant outcomes than one would expect on the basis of chance alone, (i.e., 7) an overall "pattern" is not necessarily evident.

On inspection one finds that three of the seven variables related with age are associated with dichotic performance and further that each of these dichotic variables are associated with variations within the left ear (LOS75, GSLD76, LIS76). Caution is required at this point before assuming that a significant "pattern" has been found interrelating age and dichotic performance. First, since there are 35 variables associated with dichotic performance the finding that 3 of the 35 are significantly correlated with any non-dichotic variable is not at all surprising and may simply reflect a random perturbation in a matrix of this size. The fact that each of the dichotic variables associated with Age relates to left ear performance appears to reflect a non-random pattern, and this assumption is in accord with similar observations uncovered through analysis of variance. However, any conclusion concerning the specific categories of left ear performance (i.e., LOS, GSLD, LIS) would be unwarranted given the operations of chance and the instability of these findings across years. However, some stability is apparently evident with regard to the relation of age and reading test

performance, although even here only one of the four subtests (SP) shows such consistency. Nonetheless, the emergence of a consistent positive relationship between age and reading performance implies that older children may be appreciably less impaired than their younger counterparts. This in turn may reflect changes in performance with maturation and/or the cumulative effects of prior remedial training. At this point we are unable to differentiate among these possibilities.

Given the uncertainty of interpretation in the face of these collective difficulties, we opted for a set of very conservative criteria by which to judge the efficacy of any particular outcome. These were as follows:

(1) The number of significant correlations that a particular variable achieves with the remaining set of variables must exceed three in number. When this criterion is not fulfilled, the significance outcomes which did emerge will be ignored.

(2) Since this two year analysis provides a basis for built-in replication, any particular significant interrelation must reoccur during the second year of testing. The advantage her is obvious; the liability involves the reasonable chance that non-spurious developmental changes will be discarded.

(3) Any stable pattern which does emerge within the correlation matrix must be congruent with other independent observations obtained either informally during testing or through some separate analyses of the data (e.g., analysis of variance).

When these criteria are applied to the four IQ variables (i.e., Full Scale Intelligence Quotient [FSIQ], Verbal Intelligence Quotient [VIQ], Performance Intelligence Quotient [PIQ], Block Design Performance [WISCB])

the results are as follows. First, apart from the anticipated correlations among these four variables, PIQ was found to significantly correlate with only three other variables (Response Only to Right Ear Syntactic Input [ROS75], V, and Change in Paragraph Meaning Performance [PMD]), WISCB with five variables (LOS75, Right Minus Left Ear Syntactic Performance [DSS75], Response Only to Right Ear Digit Input [ROD75, PM76, PMD), FSIQ with six (ROS75, Initial Response to Right Ear Digit Input [RID75], Secondary Response to Left Ear Digit Input [L2D76], V76, PMD) while as expected VIQ correlated significantly with the largest number (N=7) of the dichotic and reading variables (RID75, Word Meaning [WM75], Secondary Response to Right Ear Digit Input [R2S76], WM76, PMD, Change in Spelling Performance [SPD], Change in Vocabulary Performance [VD]). These results reveal a nonsignificant trend toward a greater interrelationship between IQ performance and right (five significant correlations following the elimination of PIQ results following the first criterion) rather than left ear dichotic performance. However none of the significant IQ/dichotic correlations were stable over two years and only RID75 correlated significantly with more than one variable. Thus our conclusion must be that based upon our analysis, IQ does not interrelate with dichotic performance, a conclusion supported by the results of our analysis of variance.

With regard to the interrelation of IQ and reading test performance, it was somewhat surprising to find that only the word meaning subtest (WM) generated significant and stable correlations with VIQ, while vocabulary (V) was significant only in 1976. No other reading/IQ correlation emerged at a significant level. However, there was a consistent and positive relationship between VIQ level and change in reading performance (PMD, SPD, and VD) such that the higher the level of performance on VIQ the greater the improvement

on the aforementioned reading subtests. (Thus individuals with depressed VIQ relative to their PIQ, a classic soft neurological sign associated with learning disabilities, might be expected to show the least improvement on these standard reading tests.)

We next examined the correlation matrix for evidence concerning the interrelationship of the twelve summed dichotic listening scores (i.e., variables 6-17), and the twenty-four categorical response classifications of dichotic listening (i.e., variables 18-41). Since each of these twenty-four total dichotic listening variables was assessed on each of two consecutive years, the number of cells in the submatrix involving a comparison of summed and categorical dichotic variables was 288 ([6x2][12x2]). Of these 288 possibilities, 84 were found to be significant at the $p < .05$ level, of which we can assume that 14 (288x.05) emerged as a function of chance.

When our three criteria were applied to these findings two different stable patterns were found. First there was a consistent positive relationship between the level of Total Right Ear/Digit Performance (GSRD) variable in both 1975 and 1976, with the levels of performance when the right ear responded initially (RID75, RID76) and exclusively (ROD75, ROD76) to the digit material. No stable right ear relationships for sentence material were found. The second stable pattern concerned an observed LIS75, LIS76 positive correlation with Total Left Ear/Syntax Performance (GSLS75), GSLS76, and DSS75, DSS76, respectively. Thus, one can tentatively conclude that (1) variations in first ear performance bear a stronger relationship to performance in dichotic listening than do variations in second ear performance and (2) left ear variations tend to have a greater effect on syntactic asymmetries than do right ear variations, while the right ear variations are evident with digit material.

Finally we examined the possible interrelationships of reading performance and dichotic performance. First and perhaps most conspicuously, we found that none of the change in reading performance variables (SPD, PMD, WMD, VD) bore any stable relationship to the thirty-six dichotic variables. For example, PMD significantly intercorrelated with only four dichotic variables (GSLS75, R2S75, LIS75, LOS76). According to our criterion these outcomes are too unstable to lend themselves to meaningful interpretation.

On the other hand, we did find that the 1975 reading scores significantly correlated on twenty-four separate occasions (approximately 25% of the time) with 1976 dichotic listening variable. While this pattern of outcomes did not differentiate between (1) right or left ear variables, (2) first or second ear variables or (3) syntax-digit variables, it does appear that reading performance can successfully predict general dichotic listening performance. The 1975 dichotic variable did not correlate with the 1976 reading performance at greater than chance levels. Thus while reading performance appears to predict dichotic performance, the reverse does not seem to hold.

Normal Controls

The controls differed from the L D children on several points. To begin with, whereas the Age variable in the L D group appeared to have a fragile relation to left ear performance in dichotic testing, the Age variable in the normal controls revealed a consistent positive relationship to digit material regardless of ear. Thus, significant correlations were found with R1D, Initial Response to Left Ear Digit Input (L1D), Secondary Response to Right Ear Digit Input (R2D), and Secondary Response to Left Ear Digit Input (L2D). However, Age showed only one significant correlation with a Syntax variable (L2S). These findings strongly suggest that in the control

Ss dichotic performance on syntax had reached asymptote even among the youngest Ss while digit performance continues to improve with age. In this regard it is also interesting to note that the Block Design WISC subtest, used as a measure of performance IQ, also revealed a pattern of significant positive correlations with a number of dichotic digit variables (GSRD, GSLD, RID, LID, R2D, L2D) without comparable interrelation with syntactic performance. Furthermore, this convergence of the Age and Block Design variables upon digit performance emerged despite the fact that Age and Block Design themselves were not significantly intercorrelated. We are thus left with the conclusion that performance IQ and dichotic digit performance are significantly interrelated among normal readers, while, as mentioned previously, there was no evidence of such a relation between IQ and dichotic testing in our L D population.

Summary

Our experiments make it clear that a dichotic REA is readily obtainable in reading normal children as young as 5 years of age. Moreover, the REA, present for both digit and sentence materials, is likely to be greater for sentences. This confirms our experimental hypothesis that syntactically organized material will tap the lateralized language processing mechanism more effectively than will isolated word units such as occur in strings of random digits. The use of syntactically organized material also appears to facilitate the report of the dichotic message. All analyses that incorporate material as a factor reveal a syntax relative to digit advantage.

It is of particular interest that the single possible exception to this rule involves the youngest group of children tested, viz., the kindergarten group of Experiment I. While this departure from trend is due in part to the problems inherent in the free order of report procedure, it may also reflect a significant age related effect. Specifically, young children may process words-in-a-sentence in a way that does not take full advantage of their syntactic organization. To a degree they are processed as isolated word units. Other investigators have reported similar findings using diverse paradigms (Scholes, 1969; Vanevery and Rosenberg, 1970). In all of these studies, including our own, a shift seems to occur around 5 years of age at which time the facilitating effect of syntactic organization can be seen.

It is generally true in our experiments, that the first ear to be reported exhibits a significant performance advantage. The mnemonic burden imposed upon the delay channel is manifested in the analyses by a consistent order effect. When this order effect is coupled with the characteristic tendency for the right ear to be the lead ear under free order of report conditions a firm bias toward REA emerges. These two findings provide the

strongest arguments for replacing free order procedures with controlled order of report procedures in dichotic experiments.

Additionally, the order effect often appears in interaction with other factors. As a general principle, where analyses reveal main effects, it is the weaker performance characteristic that suffers in its interaction with the order factor. For example, in all experiments it is the performance of the left ear that is more impaired and the right ear that is less impaired through delay of report. Indeed, on occasion, the right ear as delay channel maintains a performance level equal to the left ear as primary channel. Similarly the group main effect of Experiment III is enhanced on delayed report, by reason of the greater performance decrement of the L.D. children. The implication here, that mnemonic systems are particularly fragile in the L.D. children, is supported and reinforced by our finding that these children have more instances of single ear report and also have a greater tendency to lapse from the controlled report instruction. Finally, it is to be noted that order interacts with the material main effect in such a way as to yield a greater decrement on second report for digits than for sentences. These several instances of interaction with the order factor, of course, provide yet additional arguments in favor of the controlled order of report procedure.

In our Experiment III we found the administration of digit materials to present particular difficulties for the L.D. children, i.e., the group difference is accentuated by the use of digit materials. One plausible interpretation is that the L.D. child is vulnerable to the loss of cuing that would otherwise be available through the partial recall of syntactically structured and sequentially redundant material. Given the mnemonic impairment that seems to attach to these children, the cuing that ensues from the partial recall of a sentence would be especially valuable.

A similar line of reasoning would apply to the interpretation of the Material X Order interaction found in Experiment III. Obviously the recall of a sentence fragment is very useful in suggesting remaining portions of that sentence. The effect is more substantial on second report than on first report simply because performance is already at a high level on initial report.

One of our most dramatic findings is the absence of the REA for digit materials in the case of L.D. children (cf. Thompson, 1976). The REA was present in the case of sentence materials. We are now inclined to view this absence of REA for digits as a collateral expression of the language deficit in the L.D. children. As we have already argued, the administration of linguistically weak or primitive materials, such as digit strings, does not fully engage the mechanisms involved in language processing - hence the significant Material X Ear interaction in our Experiment I and Experiment III. Given a group in which the lateral specialization for language is itself weak, the REA might well be expected to be lacking. The mechanism, however, would be engaged by more appropriate linguistic materials, such as sentences, with the resultant emergence of the REA. This is precisely our finding.

For older children then, the absence of the REA with digits would constitute a useful diagnostic indicator of language impairment. For younger children, younger than those we have tested in our Experiment III, we would expect the absence of the REA with sentences to be of especial significance as a diagnostic sign.

TABLE 1

Percent of Words Correctly Reported - Experiment I

Group	
Kindergarten	52.1
Third Grade	66.3
Adult	89.5
Material	
Sentences	70.5
Digits	68.1
Ear	
Right	77.5
Left	61.1

TABLE 2

Percent of Trials Involving Single Ear Report - Experiment I

	Sentences			Digits		
	Kindergarten	Third Grade	Adult	Kindergarten	Third Grade	Adult
Right Only	52	22	02	18	08	02
Left Only	08	06	02	10	06	01

TABLE 3

Percentage of Words Correctly Reported - Experiment I Reanalysis

Group	
Kindergarten	62.5
Third Grade	71.2
Adult	85.0
Material	
Sentences	82.7
Digits	63.4
Ear	
Right	77.1
Left	69.0
Pattern	
Right-Left	72.2
Left-Right	73.9

TABLE 4

Percent of Words Correctly Reported - Experiment II

First Testing

Group	
Learning Disabled	78.4
Control	85.8
Ear	
Right	87.5
Left	76.8
Order	
First	87.8
Second	76.4

TABLE 5

Percent of Words Correctly Reported - Experiment II

Retest

Group	
Learning Disabled	79.5
Control	88.6
Ear	
Right	88.7
Left	79.4
Order	
First	88.2
Second	80.0

TABLE 6

Percent of Trials in Each Category - Experiment II

	Sentences	Digits
RO	23.4	9.5
LO	7.5	3.5
RL	32.7	21.0
LR	27.1	14.9
RLR	4.5	28.0
LRL	3.4	21.0
Other	1.5	2.2

TABLE 7

Percent of Words Correctly Reported - Experiment III

Group	
Learning Disabled	73.4
Control	84.9
Ear	
Right	82.2
Left	76.1
Material	
Sentences	87.7
Digits	70.6
Order	
First	85.8
Second	72.5

TABLE 8

Percent of Trials in Each Response Category -- Experiment III

Right Ear Lead

	Sentences	Digits
RO	15.2	12.0
LO	1.5	2.9
RL	69.3	38.6
LR	5.6	8.2
RLR	2.9	21.6
LRL	4.0	11.4
Other	1.9	5.1
	100.4	99.8

Left Ear Lead

	Sentences	Digits
RO	7.5	2.8
LO	5.4	7.5
RL	7.4	9.8
LR	64.8	36.0
RLR	9.2	17.2
LRL	3.0	21.3
Other	2.9	5.1
	100.2	99.7

TABLE 9

Percent of Trials in Which Subjects Follow Instructions -- Experiment III

	Right Ear Lead				Left Ear Lead			
	Sentences	"t"	Digits	"t"	Sentences	"t"	Digits	"t"
Controls	87.8	2.3**	55.1	2,4**	75.4	3.1**	46.2	1.5*
L. D.'s	81.8		46.0		65.1		40.8	

* df 166; $p > .05 < .10$

** df 166; $p < .01$

TABLE 10

Percent of Words Correctly Reported -

Experiment II vs. Experiment III

	Experiment II (FOR)		Experiment III (COR)	
	Sentences	Digits	Sentences	Digits
Control	89.2	74.7	90.7	79.0
L. D.'s	70.6	65.4	84.6	62.2

TABLE 11

Percent of Trials in Each Response Category for

Subjects in Experiment III

	Sentences			Digits		
	Control	L. D.	t	Control	L. D.	t
RO	09	14	2.50**	05	09	3.08**
LO	03	04	.09*	04	06	1.43*
RL	42	35	3.96***	28	21	3.79***
LR	38	33	2.38**	25	20	2.51**
RLR	05	08	3.02***	18	20	1.02*
LRL	02	05	4.84***	18	15	1.43*
Other	01	03	2.93***	02	08	4.72***

* df=165; p=n.s.

** df=165; p<.05

*** df=165; p=.01

TABLE 12

Dichotic Performance of Two L. D. IQ Groups and

Control Subjects - Experiment III

Subjects	N	Percent Correct	.95 Confidence Interval
P>V L. D.	14	71.5	66.2 - 76.8
V>P L. D.	28	75.9	71.3 - 80.6
Controls	30	84.0	79.8 - 88.2

TABLE 13

Dichotic Performance of L. D. Subjects According to IQ Pattern Compared to Age Matched Controls - Experiment III

	Sentences				Digits			
	Percent	"t"	df	p	Percent	"t"	df	p
P > V								
Right Ear	89.3	2.95	13	< .01	60.2	.85	13	> .05
Left Ear	80.8				55.7			
V > P								
Right Ear	87.8	3.94	27	< .01	69.3	1.45	27	> .05
Left Ear	80.0				66.5			
Controls								
Right Ear	92.0	3.50	29	< .01	82.7	4.50	29	< .01
Left Ear	87.0				74.2			

TABLE 14

Dichtoic Performance of Younger and Older L. D.

and Control Subjects - Experiment III

Controls

	Sentences				Digits			
	Younger	"t"	Older	"t"	Younger	"t"	Older	"t"
Left Ear	87.3	5.29[1]	88.1	4.88[2]	73.6	3.41[1]	78.8	2.89[2]
Right Ear	93.5		94.0		80.2		83.8	

L. D.

	Sentences				Digits			
	Younger	"t"	Older	"t"	Younger	"t"	Older	"t"
Left Ear	76.2	7.35[3]	82.6	4.11[4]	57.5	1.60[5]	63.7	.44[6]
Right Ear	90.4		88.9		61.7		64.7	

[1] df=48; p<.01

[2] df=44; p<.01

[3] df=29; p<.01

[4] df=41; p<.01

[5] df=29, p=NS

[6] df=41; p=NS

Table 15

Description of variables included in correlational analysis of L D performance in a two year longitudinal investigation

#	Variable	Entries
1	Age	42
	Intelligence Test Performance	
2	Full Scale Intelligence Quotient (FSIQ)	39
3	Verbal Intelligence Quotient (VIQ)	39
4	Performance Intelligence Quotient (PIQ)	39
5	Block Design Performance (WISCB)	42
	Dichotic Listening Test Performance	
6	Total Right Ear/Syntax Performance in 1975(GSRS75)	42
7	Total Right Ear/Syntax Performance in 1976(GSRS76)	42
8	Total Left Ear/Syntax Performance in 1975(GSLS75)	42
9	Total Left Ear/Syntax Performance in 1976(GSLS76)	42
10	Total Right Ear/Digit Performance in 1975(GSRD75)	42
11	Total Right Ear/Digit Performance in 1976(GSRD76)	42
12	Total Left Ear/Digit Performance in 1975(GSLD75)	42
13	Total Left Ear/Digit Performance in 1976(GSLD76)	42
14	Right Minus Left Ear Syntactic Performance in 1975(DSS75)	42
15	Right Minus Left Ear Syntactic Performance in 1976(DSS76)	42
16	Right Minus Left Ear Digit Performance in 1975(DSD75)	42
17	Right Minus Left Ear Digit Performance in 1976(DSD76)	42
18	Categories of Response in Dichotic Performance	
	(Performance on trials distingquished by following response characteristics)	
18-A	Response Only to Right Ear Syntactic Input, 1975(ROS75)	34
19	Response Only to Right Ear Syntactic Input, 1976(ROS76)	33
20	Response Only to Left Ear Syntactic Input, 1976(LOS75)	17
21	Response Only to Left Ear Syntactic Input, 1976(LOS)	20
22	Response Only to Right Ear Digit Input, 1975(ROD75)	27

#	Variable	Entries
23	Response Only to Right Ear Digit Input, 1976(ROD76)	26
24	Response Only to Left Ear Digit Input, 1975(LOD75)	22
25	Response Only to Left Ear Digit Input, 1976(LOD76)	21
26-B	Initial Response to Right Ear Syntactic Input, 1975(RIS75)	41
27	Initial Response to Right Ear Syntactic Input, 1976(RIS76)	42
28	Initial Response to Left Ear Syntactic Input, 1976(LIS76)	42
29	Initial Response to Left Ear Syntactic Input, 1976(LIS76)	41
30	Initial Response to Right Ear Digit Input, 1975(RID75)	40
31	Initial Response to Right Ear Digit Input, 1976(RID76)	40
32	Initial Response to Left Ear Digit Input, 1975(LID75)	40
33	Initial Response to Left Ear Digit Input, 1976(LID76)	38
34-C	Secondary Response to Right Ear Syntactic Input, 1975(R2S75)	42
35	Secondary Response to Right Ear Syntactic Input, 1976(R2S76)	41
36	Secondary Response to Left Ear Syntactic Input, 1975(L2S75)	41
37	Secondary Response to Left Ear Syntactic Input, 1976(L2S76)	42
38	Secondary Response to Right Ear Digit Input, 1975(R2D75)	40
39	Secondary Response to Right Ear Digit Input, 1976(R2D76)	38
40	Secondary Response to Left Ear Digit Input, 1975(L2D75)	40
41	Secondary Response to Left Ear Digit Input, 1976(L2D76)	40
	Reading Achievement Test Performance	
42	Paragraph Meaning 1975(PM75)	39
43	Paragraph Meaning 1976(PM76)	41
44	Change in Paragraph Meaning Performance (PMD)	39
45	Spelling 1975 (SP75)	28
46	Spelling 1976 (SP76)	33
47	Change in Spelling Performance (SPD)	30
48	Vocabulary 1975 (V75)	11
49	Vocabulary 1976 (V76)	17

#	Variable	Entries
50	Change in Vocabulary Performance (VD)	11
51	Word Meaning 1975 (WM75)	27
52	Word Meaning 1976 (WM76)	23
53	Change in Word Meaning 1976 (WMD)	23

A-Variables 18-25 are distinguished by virtue of the fact that the Ss were only capable of reporting content from a single ear (i.e., they behaved in those instances as though they were deaf, unaware, inattentive, and/or amnesiac, etc., for the content of the contralateral channel.

B-Variables 26-33 differ from above in that the subjects, having initiated their response to the content of one ear, were then able to accurately identify some or all of the content from the contralateral channel. Variables 26-33 are concerned, however, with the performance of the first channel reported in the sequence.

C-Variables 34-41, like 26-33, correspond to those occasions on which the Ss reported content from both channels, while unlike 26-33, variables 34-41 describe performance in the second channel reported.

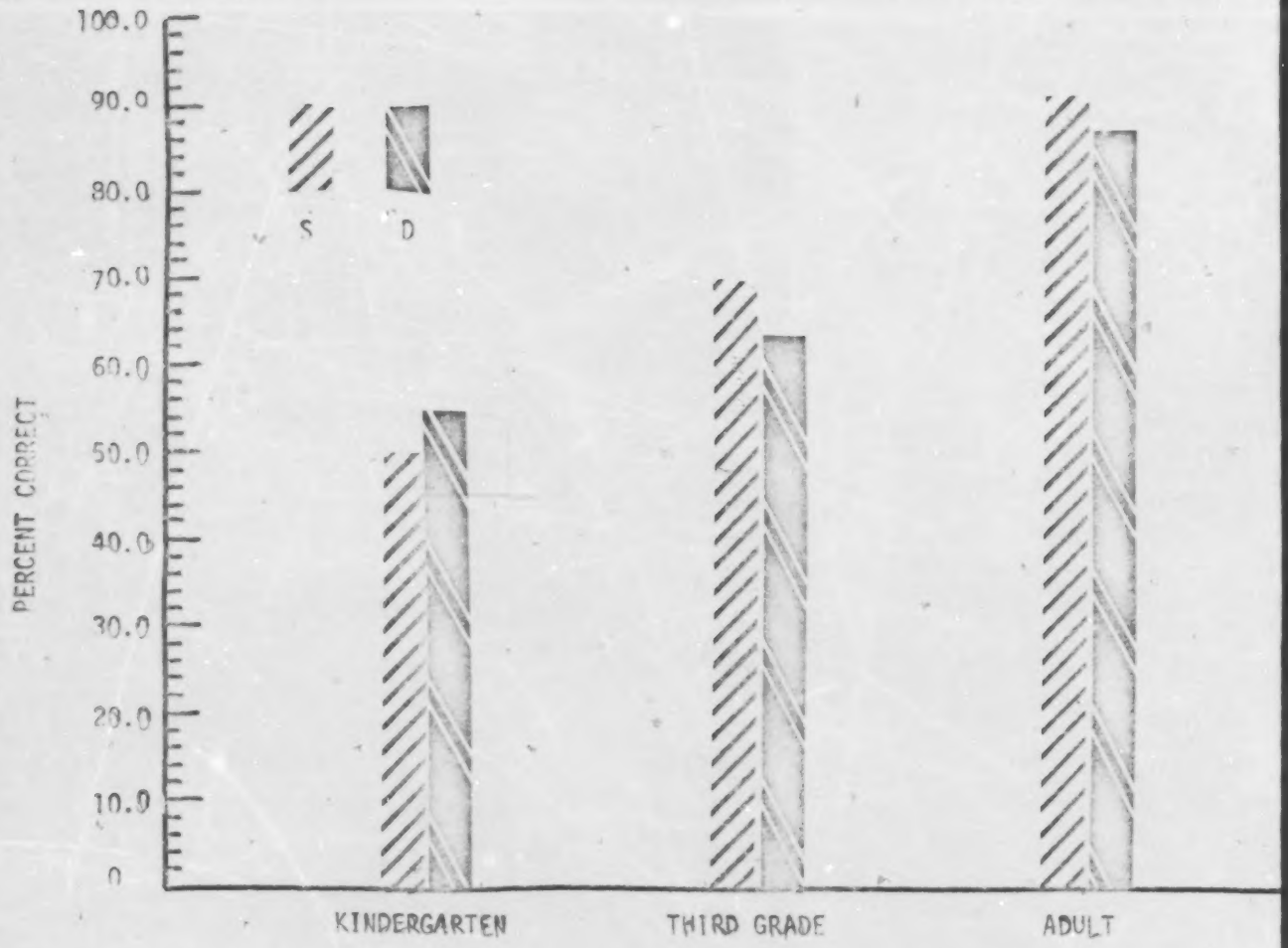

Figure 1: Performance of Kindergarten, Third Grade, and Adult Subjects on Sentences and Digits - Experiment I

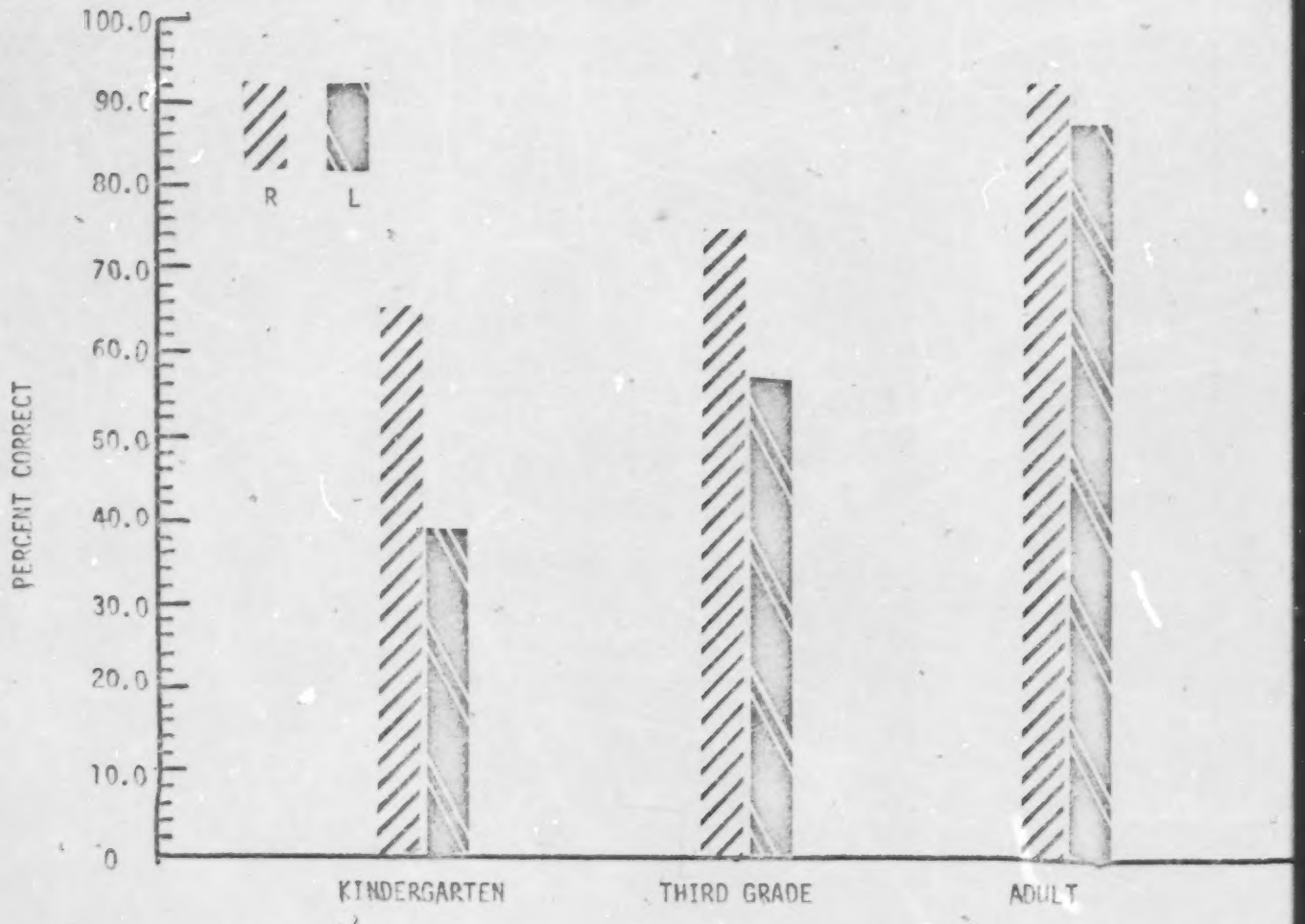

Figure 2: Right and Left Ear Dichotic Performance of Kindergarten, Third Grade, and Adult Subjects - Experiment I

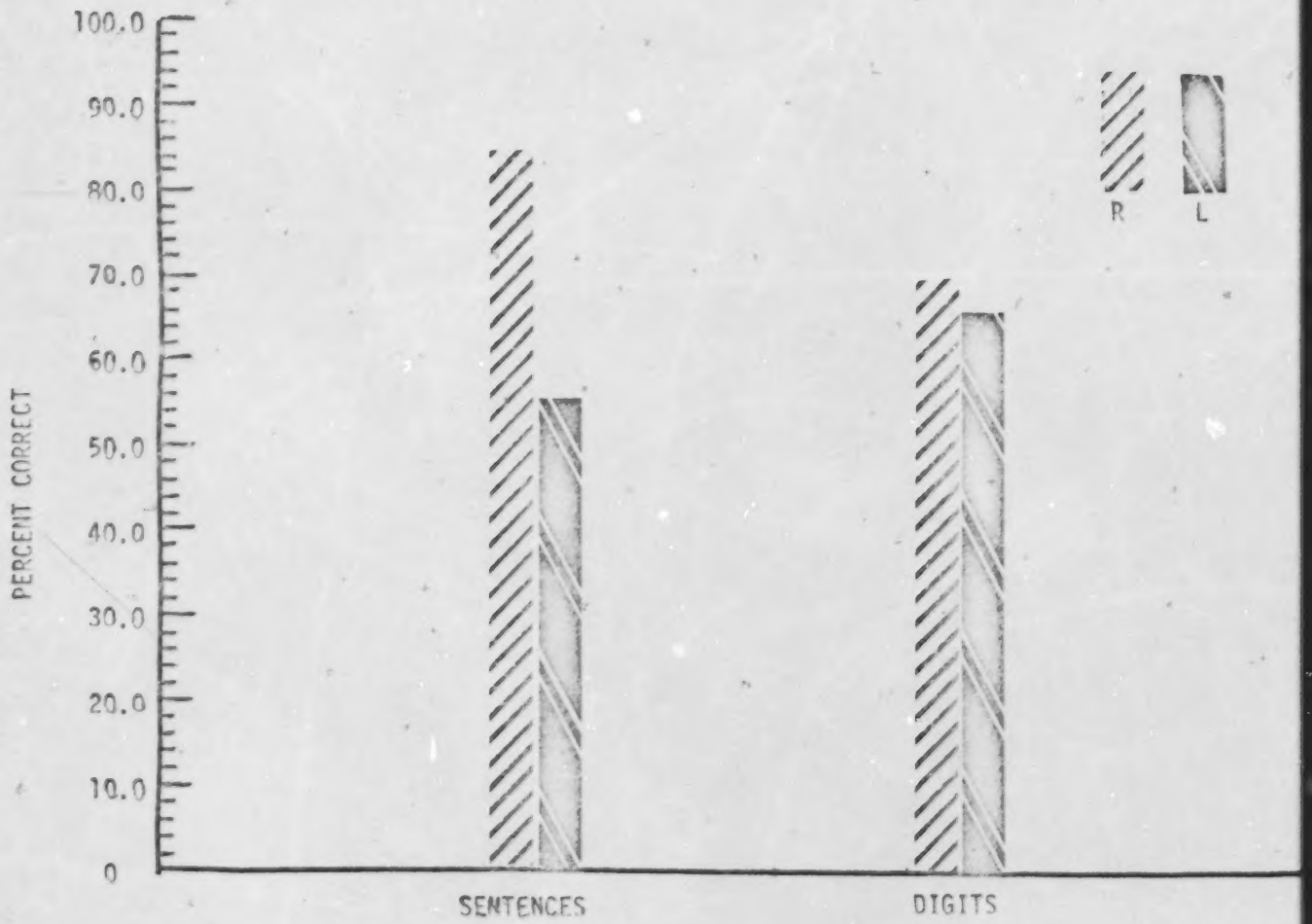

Figure 3: Right and Left Ear Dichotic Performance on Sentences and Digits - Experiment I

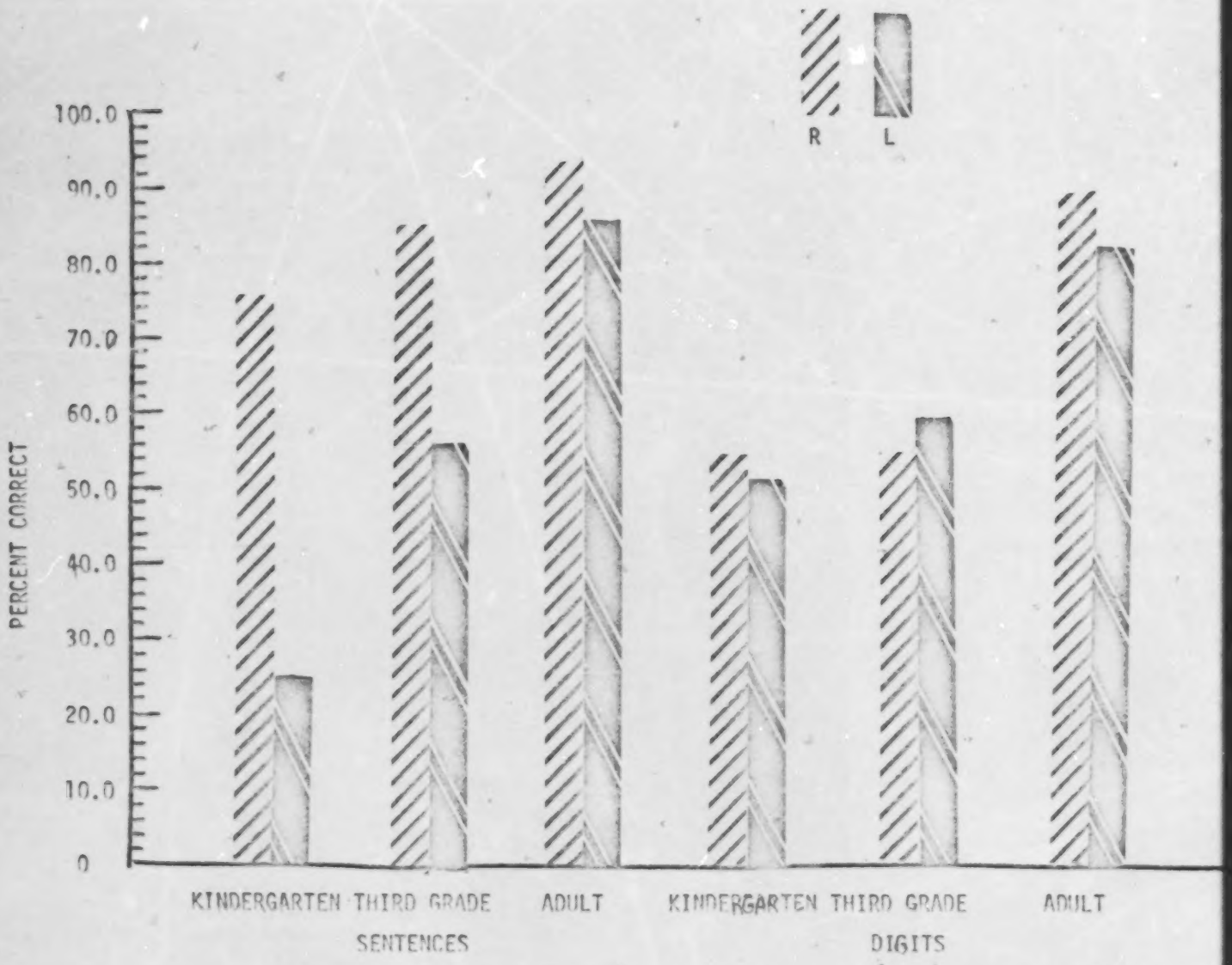

Figure 4: Right and Left Ear Perfromance of Kindergarten, Third Grade, and Adult Subjects on Sentences and Digits - Experiment I

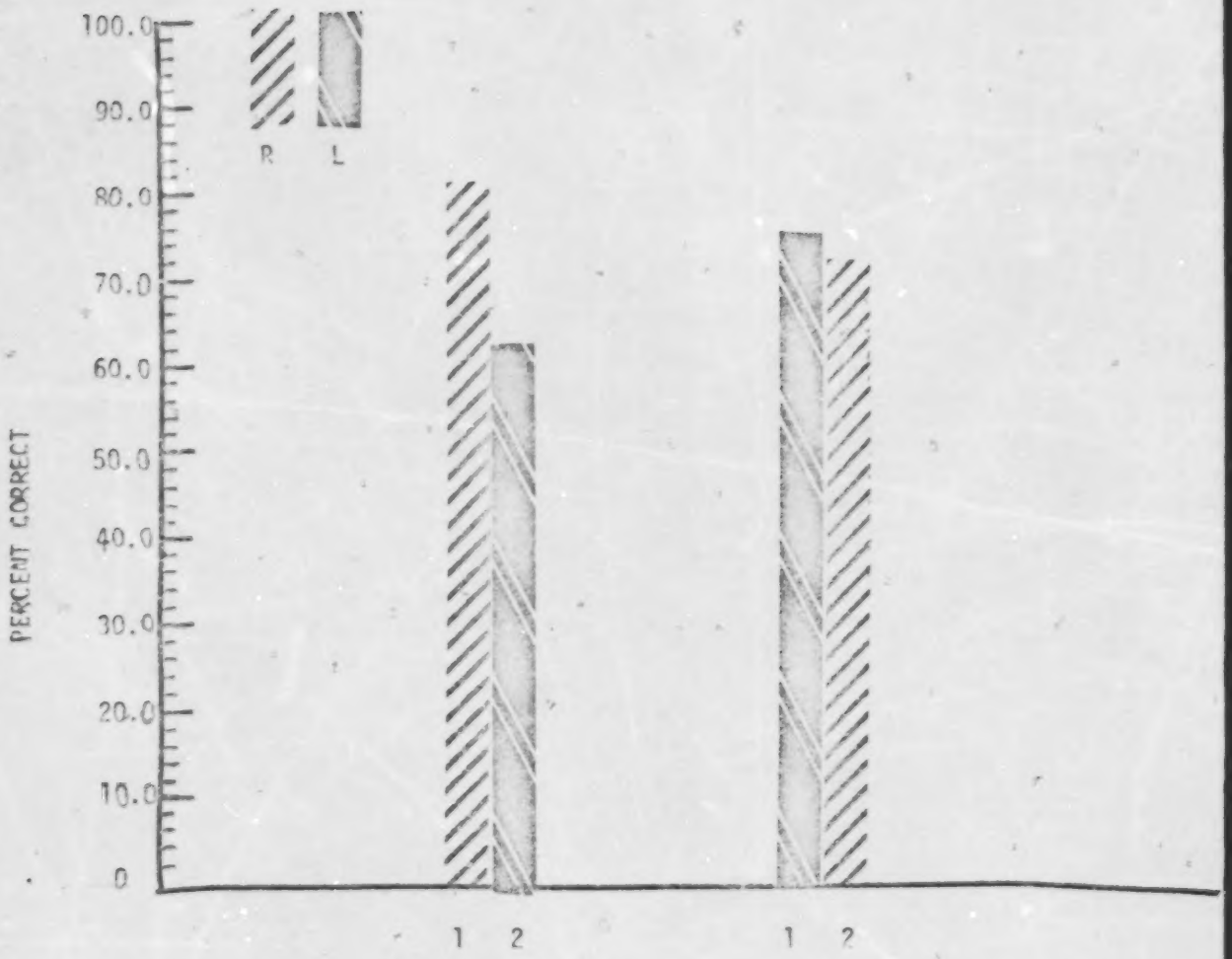

Figure 5: Right-Left and Left-Right Order of Report Patterns - Experiment I, Reanalysis

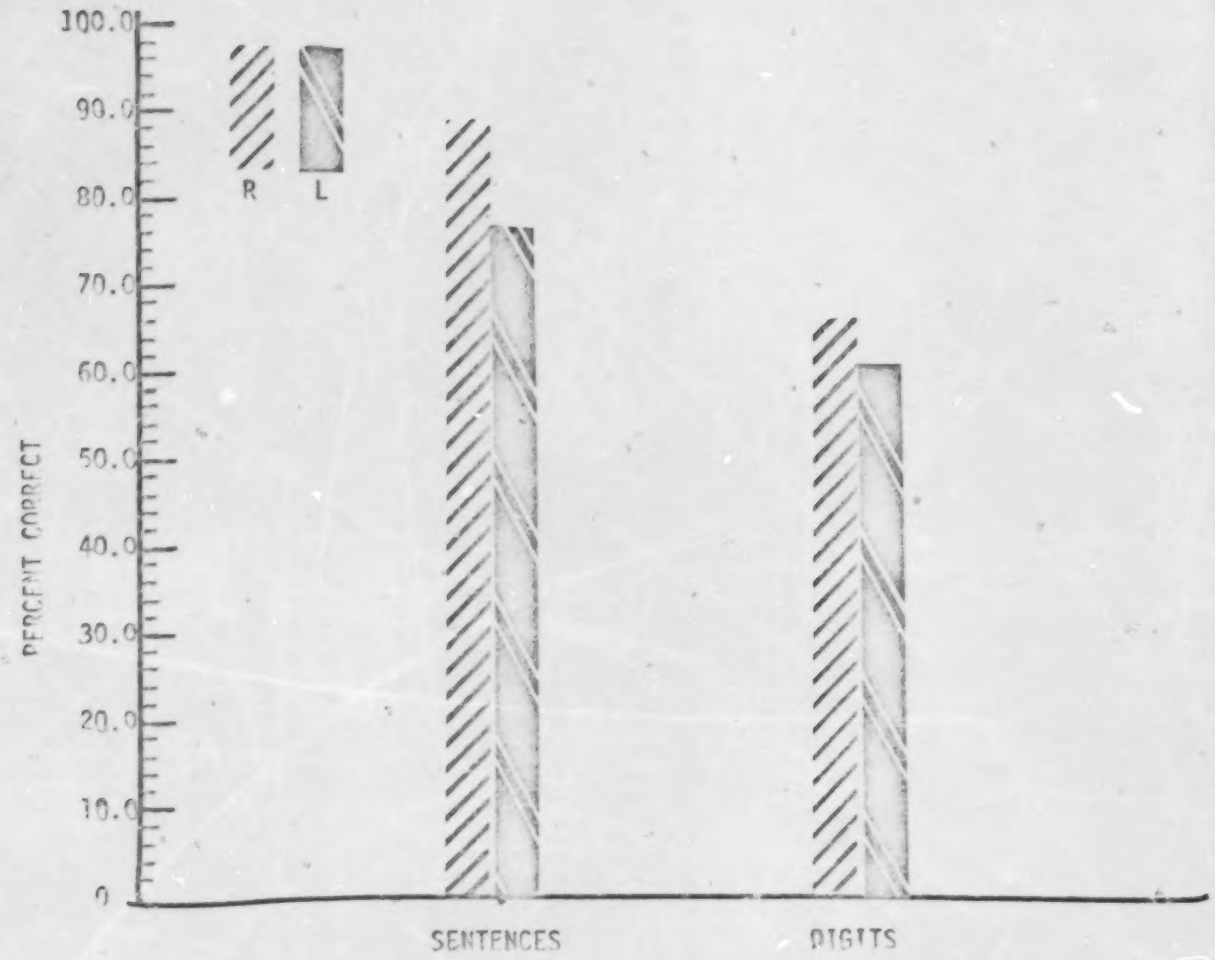

Figure 6: Right and Left Ear Dichotic Performance on Sentences and Digits - Experiment I, Reanalysis

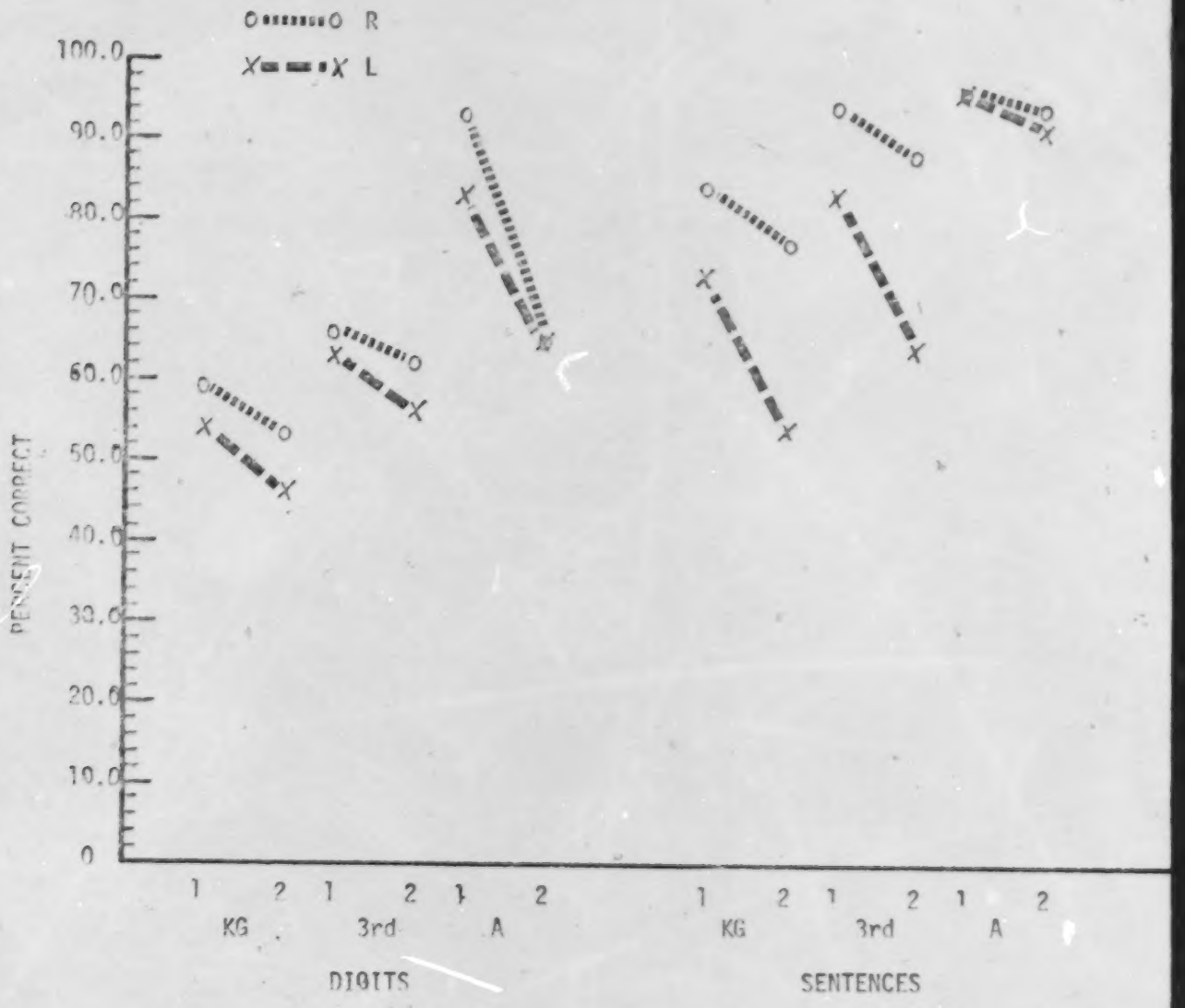

Figure 7: Right and Left Ear Order of Report Patterns on Sentences and Digits for Three Subjects Groups - Experiment I, Reanalysis

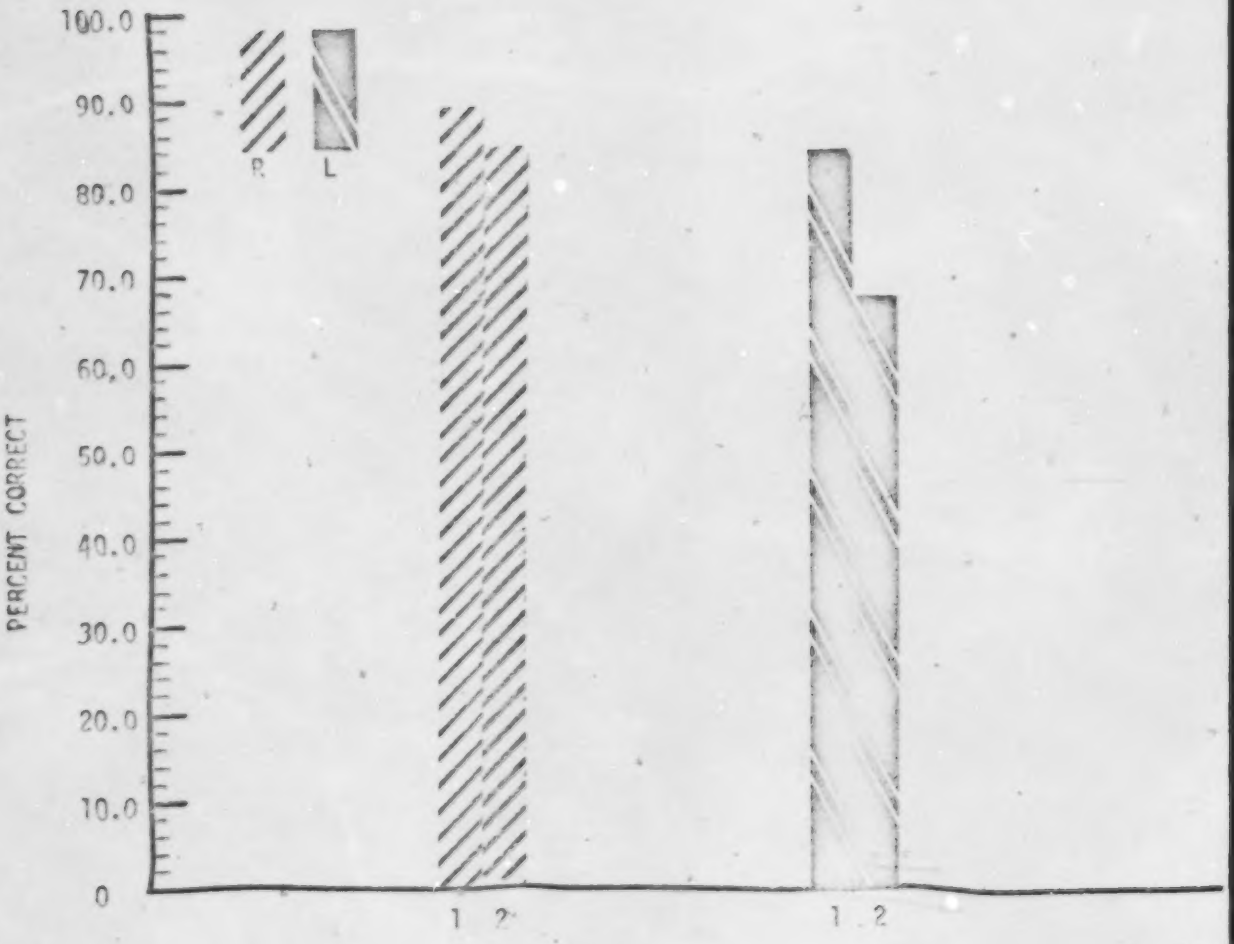

Figure 8: Right and Left Ear Performance When Reporting First and When Reporting Second - Experiment II

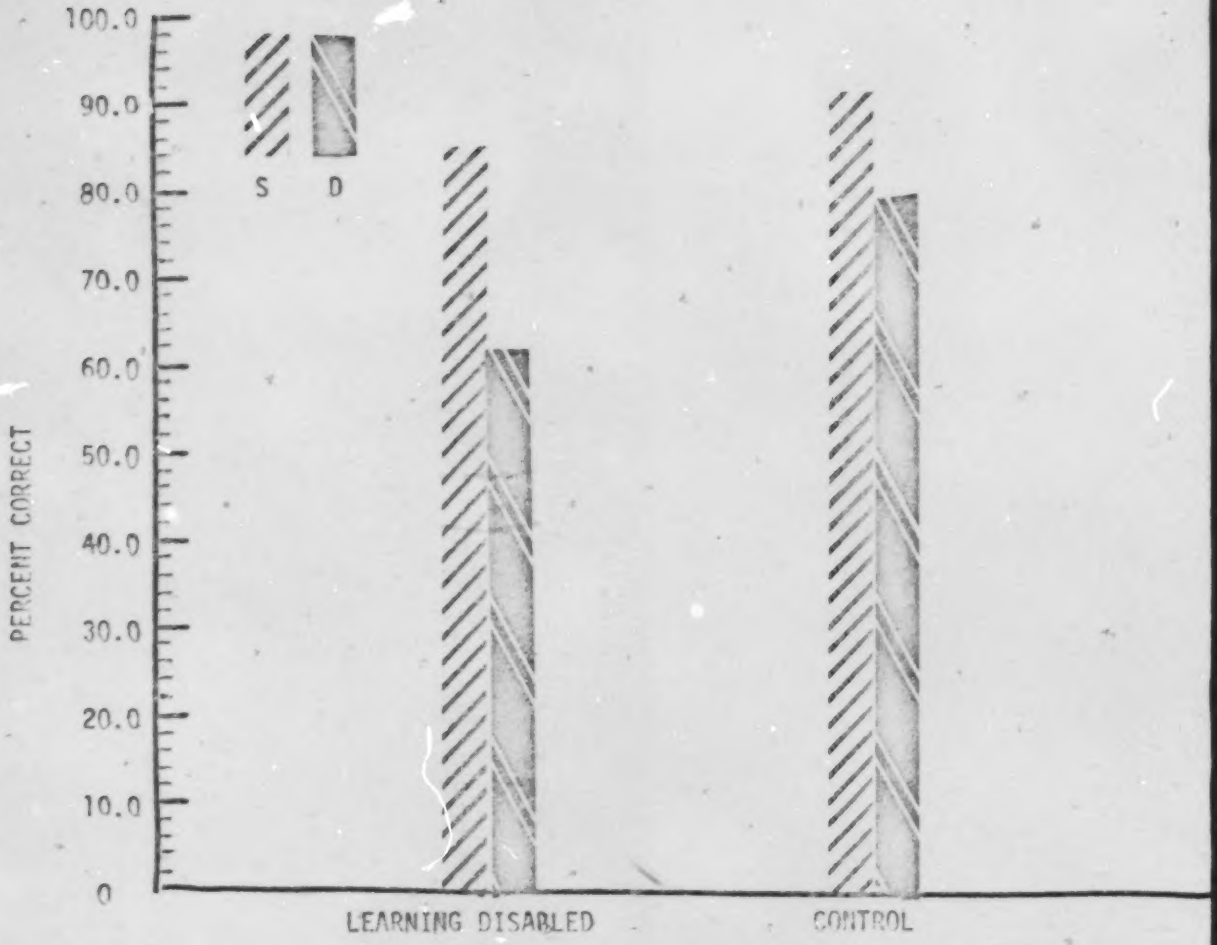

Figure 9: Performance of Learning Disabled and Control Subjects on Sentence and Digit Materials - Experiment III

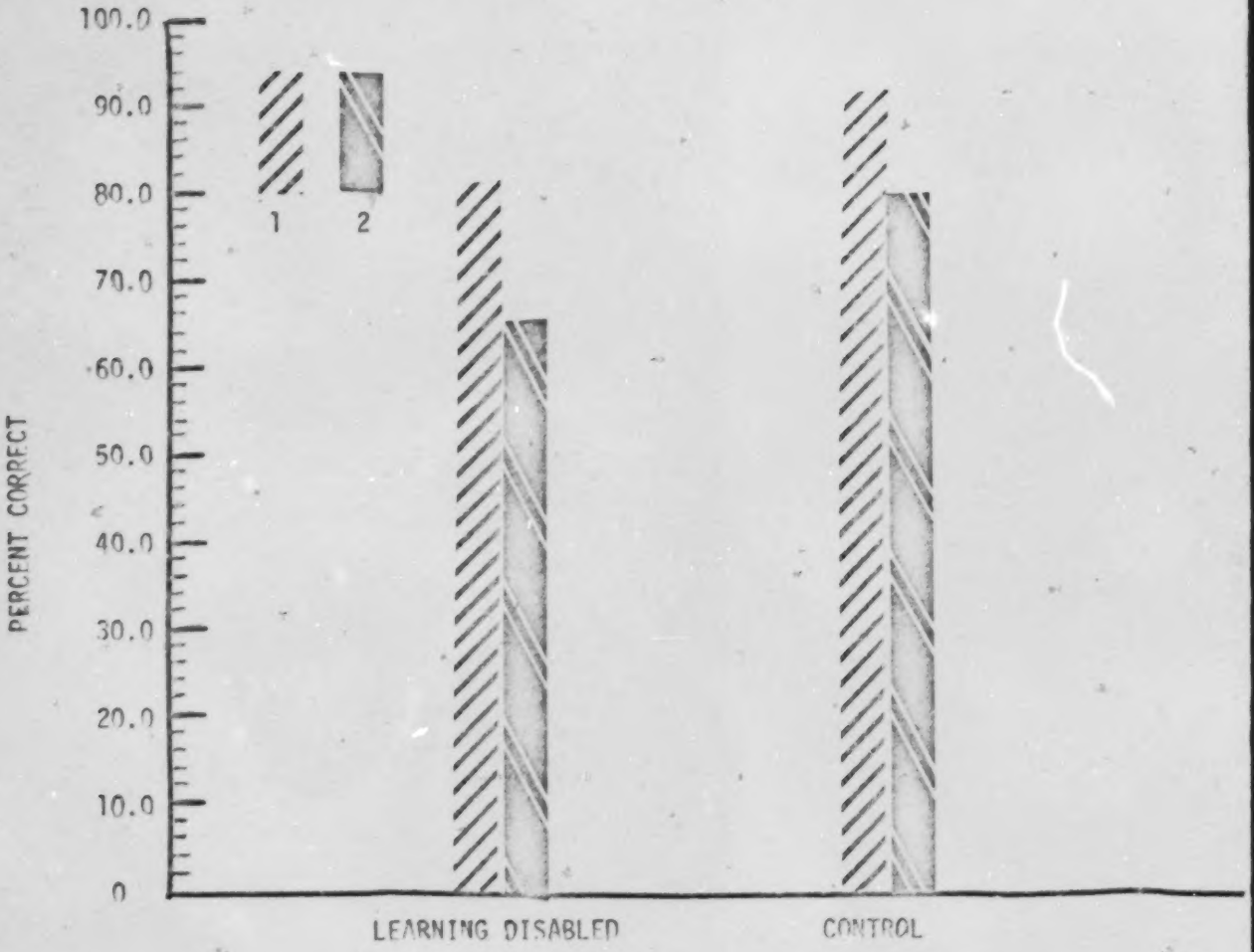

Figure 10: Performance of Learning Disabled and Control Subjects on First and Second Report - Experiment III

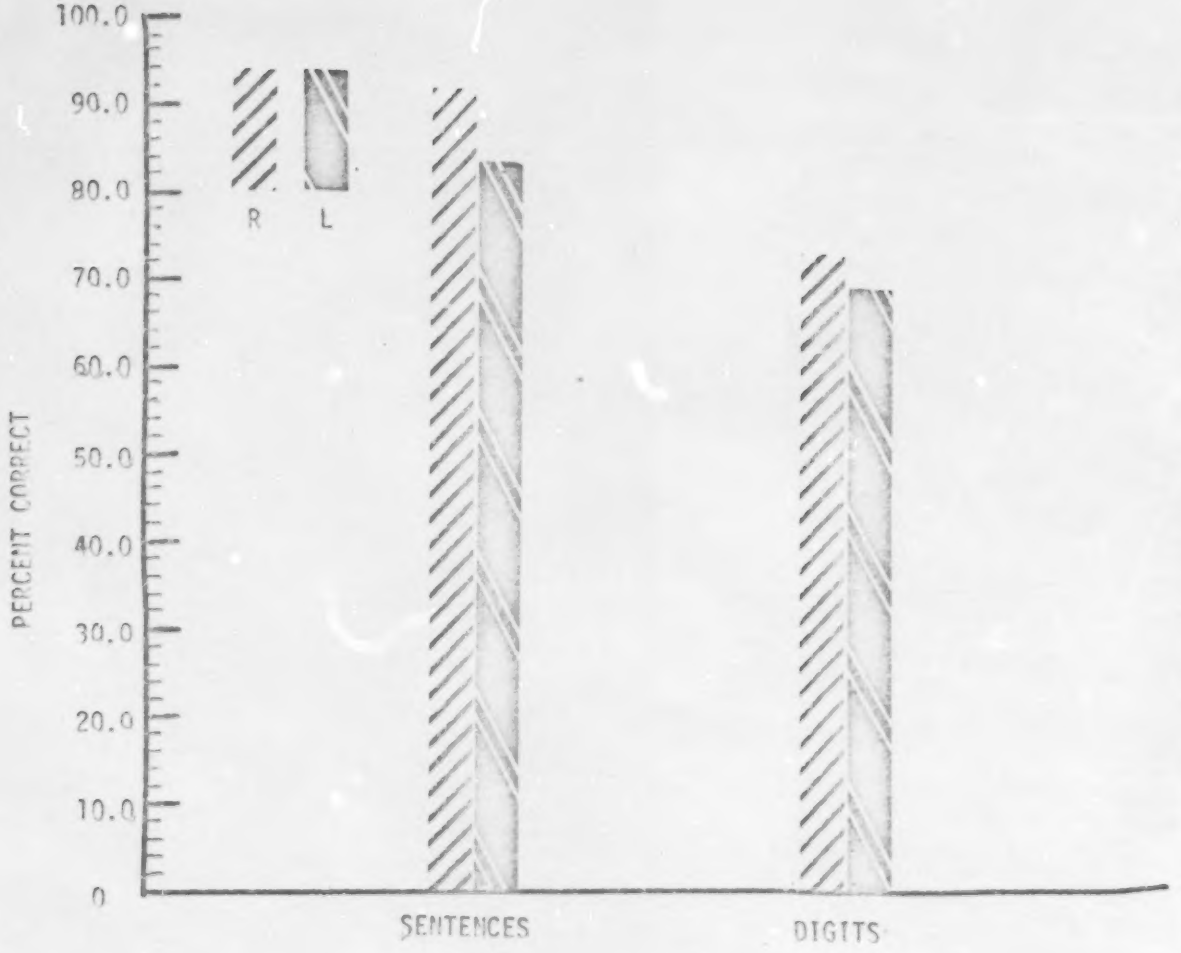

Figure 11: Right and Left Ear Performance on Sentences and Digits - Experiment III

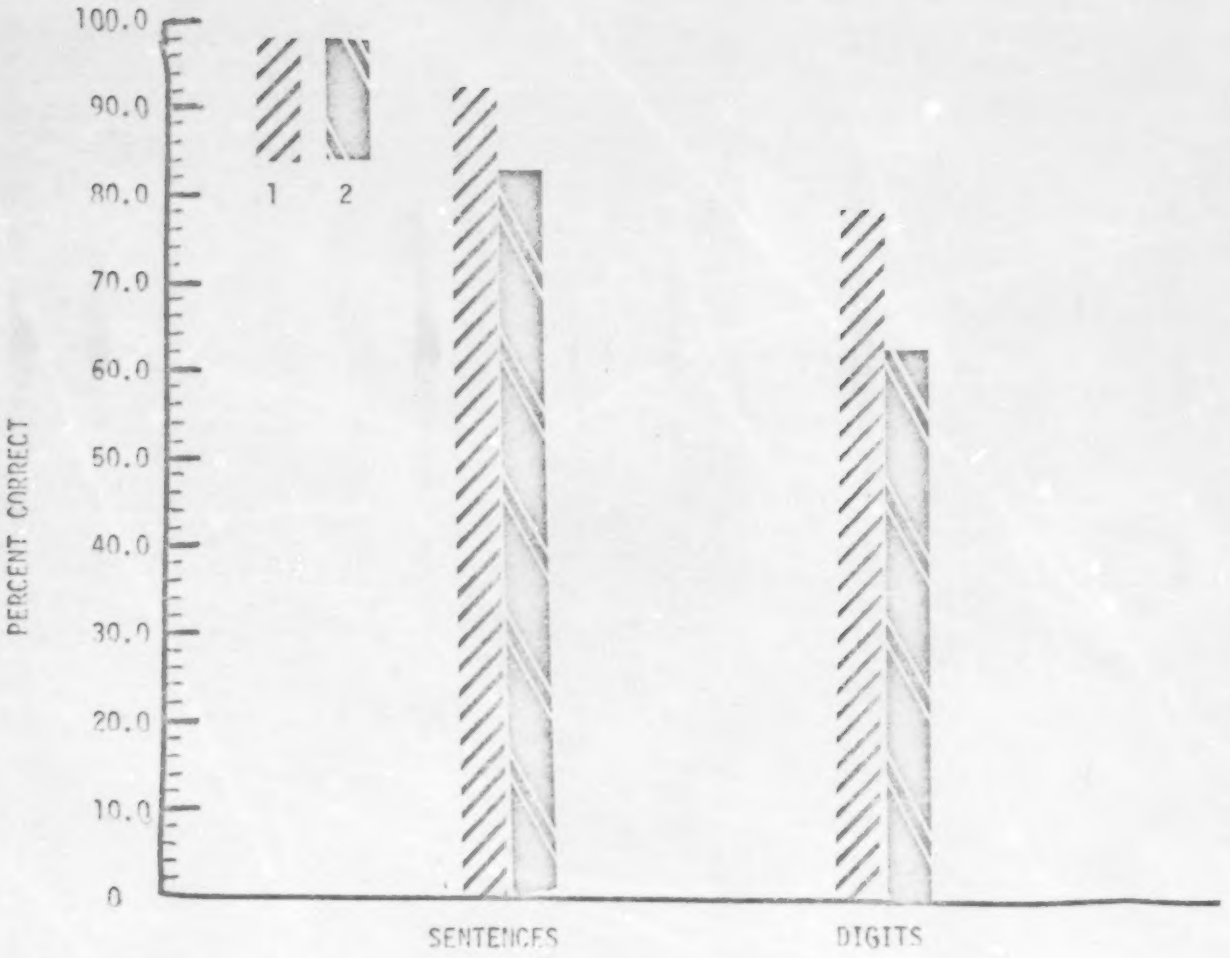

Figure 12: Performance on Sentences and Digits Under Conditions of First and Second Order of Report - Experiment III

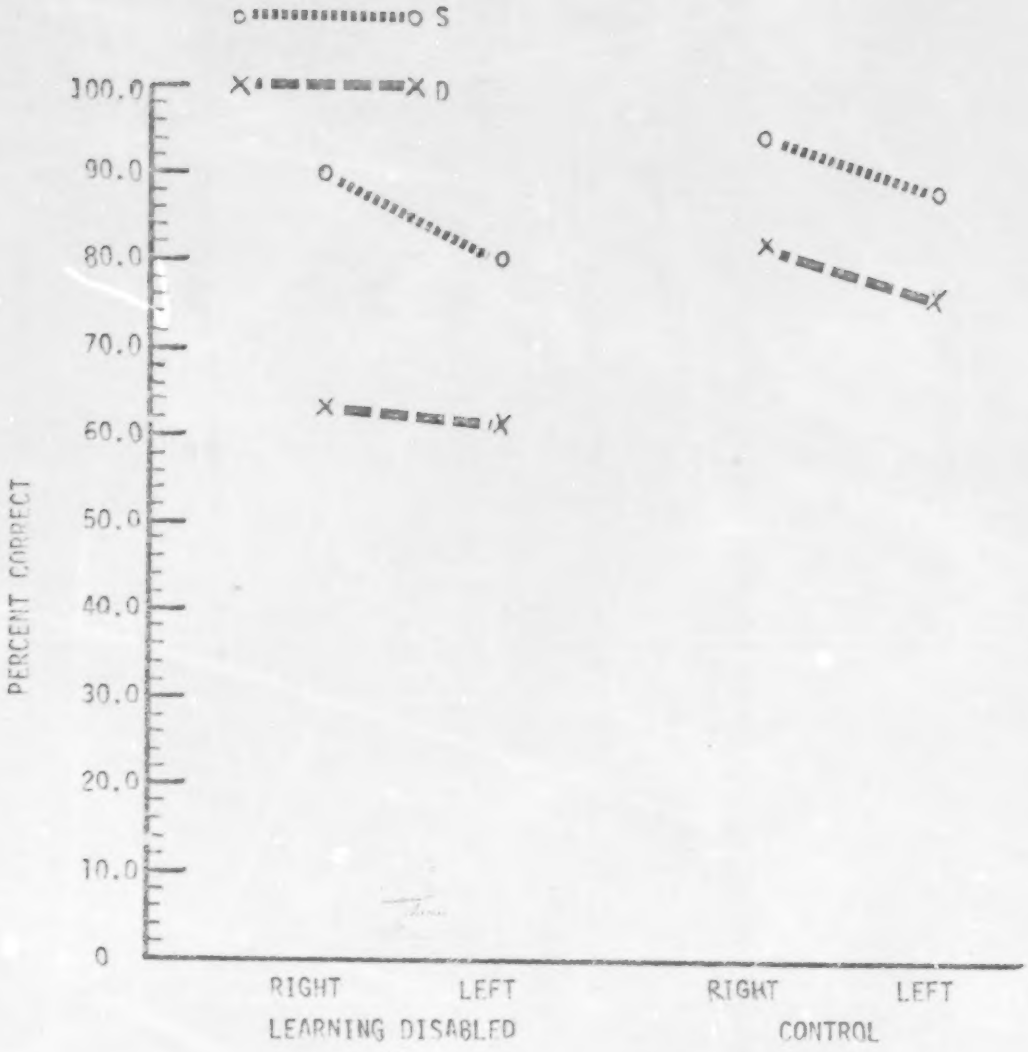

Figure 13: Right and Left Ear Performance of Learning Disabled and Control Subjects on Sentences and Digits - Experiment III

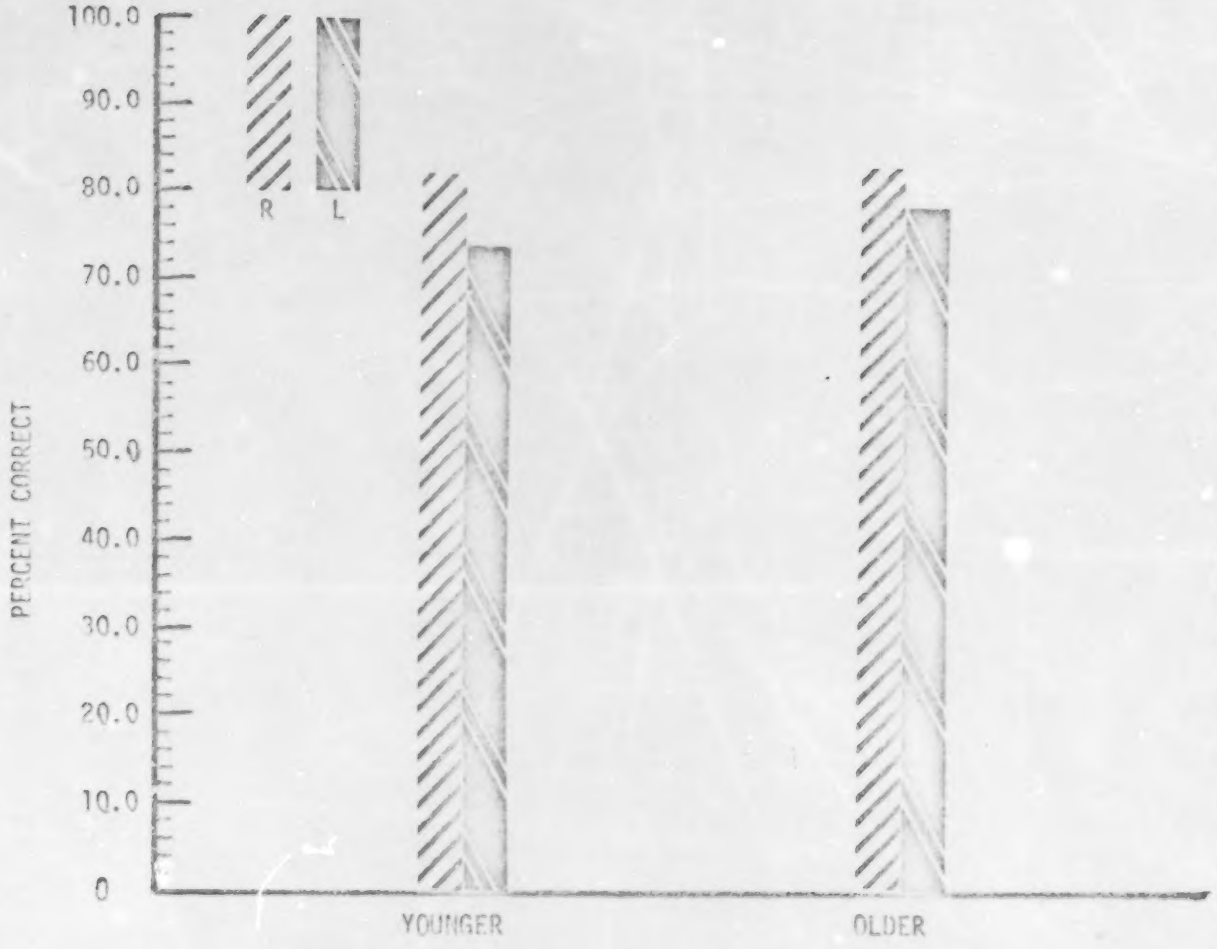

Figure 14: Dichotic performance of younger and older children, Experiment III

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SENTENCE PAIRS*

Trial	Channel A	Channel B
1	my	the
	bike	little
	is	child
	broken	played
2	doing	jumping
	that	rope
	was	is
	not	very
	nice	easy
3	she	I
	hurt	always
	herself	dress
	badly	myself
4	our	the
	teacher	school
	gave	bus
	out	was
	some	here
	books	early
5	an	the
	old	water
	man	is
	laughed	cold
6	the	we
	woman	went
	lost	for
	her	a
	hat	walk
7	lunch	the
	was	two
	served	cups
	early	were
	today	broken
8	who	when
	did	are
	you	you
	see	going
	today	home
9	He	You
	washed	fooled
	himself	yourself
10	they	we
	could	made
	not	fun
	help	of
	themselves	ourselves
11	which	how
	is	are
	it	you
12	they	she
	often	combed
	took	her
	care	hair
	of	by
	themselves	herself
13	how	where
	are	have
	your	you
	friends	been
14	he	the
	threw	boy
	the	failed
	ball	his
	hard	test
15	the	they
	girl	are
	sang	sick
16.	baby	eggs
	was	were
	washed	broken
17	playing	climbing
	is	a
	more	tree
	fun	is
	than	very
	school	hard

* Ear to be reported first switches after 13 trials.

SENTENCE PAIRS

Trial	Channel A	Channel B
18	smoking	swimming
	is	was
	bad	fun
19	the	the
	horse	fire
	runs	was
	fast	hot
20	telling	running
	lies	makes
	is	me
	wrong	tired
21	the	the
	phone	girl
	rang	sings
22	what	where
	is	do
	your	you
	new	go
	teacher	to
	like	school
23	our	the
	clothes	game
	were	was
	cleaned	played
	and	at
	pressed	night
24	their	his
	cat	gloves
	played	were
	with	nice
	a	and
	ball	warm
25	his	the
	skates	food
	were	was
	stolen	cooked
26	the	he
	phone	runs
	rang	fast